Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Machinist's Mate 1 & C,* NAVEDTRA 10525-E.

Naval Education And Training Program Management Support Activity

MACHINIST'S MATE 1 & C

NAVEDTRA 10525-E

DEPARTMENT OF THE NAVY ★ CHIEF OF NAVAL EDUC AND TNG ★

1987 Edition Prepared by
MMCM Teddy E. Vaughan

MC.M.01

PREFACE

This Rate Training Manual (RTM) with the Nonresident Career Course (NRCC) form a self-study package. They will enable Machinist's Mates to acquire the theoretical knowledge and operational skills required to advance to Machinist's Mate First Class and Machinist's Mate Chief. Combined with the necessary practical experience and a review of other applicable training manuals, a knowledge of the information in this self-study package will help the student meet advancement requirements.

This package is designed for individual study and to support on-the job training. It provides subject matter that relates directly to the occupational qualifications of the Machinist's Mate rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This self-study package was prepared by the Naval Education and Training Program Management Support Activity, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Schools Command, Great Lakes, Illinois; Naval Safety Center, Norfolk, Virginia; Naval Development and Training Center, San Diego, California; and Naval Sea Systems Command, Washington, D.C.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

INTRODUCTION

As you prepare for advancement to petty officer first class, you have already learned that continuous training is essential if you are to reach your personal goals and help carry out the mission of the Navy.

This training manual helps you continue that training by providing general information about your rating at the E-6 and E-7 levels. It is only one of your sources of information, but probably your best source of general information. Other sources will be discussed later in this chapter. This is not a technical manual; it should not be used as a maintenance guide or for in-depth training on a specific piece of equipment. However, knowledge of the information in this manual, combined with your everyday practical experience, will help you learn to perform your assigned tasks and accept greater responsibilities.

INCREASED RESPONSIBILITIES

You have already learned that advancement brings both increased rewards and increased responsibilities. Start now to consider these rewards and responsibilities that come with advancement to MM1 or MMC.

You know many of the advantages of advancement: higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your career. By this time, you have probably discovered that one of the most enduring rewards is the personal satisfaction you find in developing your skills and increasing your knowledge.

As you reach each higher level in your rating, you and the Navy benefit in two ways from your greater knowledge and skill. First, you become more valuable as a technical specialist in your own rating. Second, you become more valuable as a person who can supervise, lead, and train others. The extent of your contribution depends upon your willingness and ability to accept increasing responsibilities in military matters and in matters relating to the occupational requirements of your rating.

Every petty officer is a military person as well as a technical specialist. Therefore, your responsibilities for military leadership are about the same as those of petty officers in other ratings. However, your responsibilities for technical leadership are special to your rating and the nature of your work. Operating and maintaining the ship's main propulsion plants and auxiliary equipment is a job of vital importance. It is also a teamwork job. It requires a special kind of supervisory ability that can be developed only through a high degree of technical competence and a deep sense of personal responsibility.

Your increasing responsibilities for military and technical leadership extend both upward and downward. You will be expected to translate the general orders given by officers into detailed, practical, on-the-job language that can be understood and followed even by relatively inexperienced personnel. It is up to you to see that your juniors do their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted personnel.

You will have continuing responsibilities for training even if you have a highly skilled and well-trained engine-room or auxiliary force. You will always be training lower rated personnel for advancement. Some of your best workers may be transferred, and inexperienced or poorly trained personnel may be assigned to you. A particular job may call for skills that none of your personnel have. These and similar problems require you to be a specialist in formal and informal training.

You will have increasing responsibilities for working with others. As you advance, you will find that many of your plans and decisions affect a large number of people. Some of them are not in the engine room and some are not even in the engineering department. Therefore, it becomes increasingly important to understand the duties and responsibilities of personnel in other ratings. Be a technical specialist in your own field and learn as much as you can about the work in other

ratings. Plan your work so that it will fit with the overall mission of the organization.

As your responsibilities increase, your ability to communicate clearly and effectively should also increase. A good leader and supervisor speaks and writes in such a way that others can understand exactly what is meant.

One requirement for effective communication is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Another requirement of effective communication is the use of technical terms. Learn and use the technical language of the Machinist's Mate rating. It helps you receive and convey information and ideas accurately, read technical publications, and take advancement examinations. You will be at a disadvantage if you do not understand and use these terms. It is particularly important when you are dealing with lower rated personnel who may be confused by careless use of technical terms.

You will have increased responsibilities for keeping up with new developments. Practically everything in the Navy—policies, procedures, equipment, publications, and systems—is subject to changes. As an MM1, and more so as an MMC, you must keep yourself informed about changes and new developments that affect your rating and your work.

Some changes will be called directly to your attention, while you will have to look for others. You should develop a special kind of alertness for new information. Keep up to date on all available sources of technical information. Keep an open mind about propulsion plants and associated equipment. New types are constantly being designed and tested, and existing types are being modified.

As you prepare to assume greater responsibility, you should be familiar with the military requirements and the appropriate rate training manuals. Other materials that may be required or recommended are listed in the current edition of the *Bibliography for Advancement Study*, NAVEDTRA 10052. Other sources of information are described later in this chapter.

MACHINIST'S MATE RATING

Machinist's Mates operate and repair a wide variety of equipment. Those who are assigned to the engine room (M division) operate and maintain the ship's main engines and associated equipment such as pumps, distilling plants, compressors, valves, oil purifiers, heat exchangers, governors, reduction gears, main shafts, and shaft bearings.

Machinist's Mates who are assigned duties other than in engine rooms maintain and repair machinery such as steering engines, anchor windlasses, cranes, winches, elevators, laundry and galley equipment, and air-conditioning and refrigeration equipment. Machinist's Mates also perform duties in the generation, stowage, and transfer of some industrial gases.

Machinist's Mates are assigned to all types of steam-driven surface ships. Your duties will depend largely on the type of ship to which you are assigned. For example, if you are assigned to a tender or repair ship, you will work mostly with repairs and services to other ships. You may choose a specialized area such as air conditioning and refrigeration or the manufacture of industrial gases. These two fields require special training, which you may get in the appropriate schools.

Duty at most shore stations is related to training in your field of specialization. You may be assigned as an instructor either at one of the schools or at a recruit training station. To qualify for instructor duty, you must successfully complete a course in instructor training. Other assignments ashore may include attache duty and recruiting duty.

NAVY ENLISTED CLASSIFICATION CODE

The Machinist's Mate rating is a source of a number of Navy enlisted classification codes (NECs). NECs reflect special knowledge and skills within certain ratings. The NEC coding system improves management control over enlisted skills by accurately identifying billets and personnel. It also helps ensure maximum use of skills in distribution and detailing. There are a number of NECs that you may earn if you satisfactorily complete an applicable course of instruction at a specified Navy school. More detailed information regarding NECs can be found in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, section II, "Navy Enlisted Classification," NAVPERS 18068-D.

REQUIREMENTS FOR ADVANCEMENT

To qualify for advancement, you must meet the following criteria:

- Have the required minimum amount of time in service and grade

- Complete the required military and occupational training manuals and courses

- Demonstrate the ability to perform all the practical requirements for advancement by completing the Personnel Advancement Requirements (PAR) Program, NAVPERS 1414/4

- Be recommended by your commanding officer

- Demonstrate your knowledge by passing written examinations based on the military requirements for advancement and the occupational qualifications for advancement

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to "add a stripe." The number of personnel in each rate and rating is controlled on a Navy-wide basis. Therefore, the number that may be advanced is limited by the number of vacancies that exist. When the number of personnel passing the examination exceeds the number of vacancies, some system must be used to determine who may or may not be advanced. The system used for advancement is called the final multiple. This means that a multiple of factors will determine who is advanced and who is advanced ahead of others. The final multiple combines credit for performance (evaluation and CO recommendation), knowledge (advancement exam), and seniority (time in service and grade). The details of the advancement system may be found in *Military Requirements for Petty Officer First Class*, NAVEDTRA 10046, and *Military Requirements for Chief Petty Officer*, NAVEDTRA 10047.

STANDARDS

At this stage in your naval career, you are well aware that the Navy has established certain standards to help you obtain the best results from your training program. These standards provide step-by-step procedures for you to follow to gain the maximum knowledge as you progress in your rate.

NAVAL STANDARDS

Naval standards are requirements that apply to all ratings. Naval requirements for advancement to first class and chief petty officer deal with naval organization, administrative responsibilities, military conduct, military justice, security, watch standing, and other subjects. These standards are skills and knowledges (other than those defined by occupational standards, which are discussed later in this chapter). They are essential to your overall effectiveness in the performance of your duty.

Before you can be advanced, you must complete one of these two correspondence courses, depending on the rate you are seeking: *Military Requirements for Petty Officer First Class*, NAVEDTRA 10046, or *Military Requirements for Chief Petty Officer*, NAVEDTRA 10047. The information you gain from these courses will prepare you to pass the military leadership examination.

OCCUPATIONAL STANDARDS

Occupational standards are requirements that are directly related to the work done by each rating. The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068, has replaced the "quals" manual and the NEC manual. Section I contains the occupational and naval standards for advancement to each paygrade in each enlisted rating. Section II contains the NECs.

The complete occupational standards for the MM1 and MMC rates are shown at the end of this chapter as figure 1-1 and are covered in this manual. This text may not be considered correct in areas affected by later changes in these occupational standards. Your ESO should have a current edition of the occupational standards that apply to your rating.

PERSONNEL QUALIFICATION STANDARDS (PQS)

The Personnel Qualification Standards (PQS) Program is the result of an increasing need for greater technical know-how within the Navy. The PQS documents are the guides to the qualification of personnel.

PQS exist to "let all personnel know their job, their place in the ship, their responsibilities to shipmates and their purpose in fighting." The system places most of the responsibility for learning on

the individual and encourages self-achievement. The PQS describe the knowledge and skills you must have to correctly perform your duties. They provide a convenient record of accomplishment. They also provide a means whereby your progress and the progress of those who work for you can be monitored.

The PQS for a specific piece of equipment or watch standing requirements are in book form. Each PQS guides you toward a qualification by telling you exactly what you must learn to achieve your goals. PQS are divided into four main subdivisions:

- 100 series—Theory
- 200 series—Systems
- 300 series—Watch stations
- 400 series—Qualification cards

Theory

The 100 series describes the basic knowledge, equipment, or duties of a Machinist's Mate. It is a list of questions about all of the various engineering fundamentals, including safety. Each portion of the theory section has a list of references that contains the answers for the individual items listed.

Systems

In the 200 series, your study will show you what the systems do, how they do it, and many other aspects of their operation. This is accomplished by breaking a piece of machinery down into functional sections and studying all of its functional parts. This section also covers how the components and component parts work together to perform the function of the system.

Watch stations

The 300 series describes the procedures that you must know to properly operate and maintain the machinery. You will be asked to perform and discuss various procedures and to demonstrate your ability to cope with the machinery at your watch station.

Qualification Cards

The qualification card lists the steps you must complete in the 100, 200, and 300 series of the standards. These cards are your guide, references, and record of achievements. As an MM1 or MMC, you will find these qualification cards are a good tool to use in evaluating your training as well as that of your trainees.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to learn more about it. It is important to know the references to consult for detailed, authoritative, up-to-date information on any subject.

Some of the publications discussed here are subject to change or revision from time to time. Some will be changed at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

NAVEDTRA PUBLICATIONS

The Naval Education and Training Command and its field activities come directly under the command of the Chief of Naval Education and Training instead of the Chief of Naval Personnel. Training materials published by the Naval Education and Training Command are designated as NAVEDTRA. NAVTRA and NAVPERS designators on publications will remain as originally assigned. However, the designators of publications printed hereafter will be changed to NAVEDTRA as each publication is revised.

The naval training publications described here include some that are absolutely essential for anyone seeking advancement and some that, although not essential, are extremely helpful.

NAVEDTRA 10052

Bibliography for Advancement Study, NAVEDTRA 10052, lists required and recommended rate training manuals and other reference materials to be used by personnel working for advancement.

NAVEDTRA 10052 is revised and issued annually by the Chief of Naval Education and Training. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be sure you have the most recent edition.

Extensive changes in standards may occur in any rating between the annual revisions of NAVEDTRA 10052. If so, a supplementary list of study material may be issued in the form of a BUPERS notice. When you are preparing for advancement, check to see whether changes have been made in the standards for your rating. If changes have been made, see whether a BUPERS notice has been issued to supplement NAVEDTRA 10052 for your rating.

The required and recommended references are listed by paygrade level in NAVEDTRA 10052. Remember that you are responsible for all references at lower paygrade levels, as well as those listed for the paygrade you are seeking.

Rate training manuals that are marked with an asterisk (*) in NAVEDTRA 10052 are MANDATORY at the indicated paygrade levels. A mandatory training manual may be completed by (1) passing the appropriate nonresident career course based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the mandatory training manual; or (3) in some cases, successfully completing an appropriate Navy school.

You should note that all references listed in NAVEDTRA 10052, whether mandatory or recommended, may be used as source material for the written examinations at the appropriate paygrade. In addition, references listed in this rate training manual may also be used as source material for examination questions.

Rate Training Manuals

Rate training manuals are written for the specific purpose of helping you prepare for advancement. Some manuals are general in nature and are intended for use by more than one rating. An example is *Tools and Their Uses*, NAVEDTRA 10085-B. Others, such as this one, are for a specific rating.

Rate training manuals are revised from time to time to bring them up to date. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. The most recent addition may be found in the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061.

The following rate training manuals are specially prepared to provide information on the military requirements for advancement:

- *Basic Military Requirements,* NAVEDTRA 10054
- *Military Requirements for Petty Officer Third Class,* NAVEDTRA 10044
- *Military Requirements for Petty Officer Second Class,* NAVEDTRA 10045
- *Military Requirements for Petty Officer First Class,* NAVEDTRA 10046
- *Military Requirements for Chief Petty Officer,* NAVEDTRA 10047

Each of the military requirements manuals is mandatory at the indicated paygrade. In addition to the information on military requirements, these books also contain a good deal of other information. Some examples are the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead personnel; and how to meet your increasing responsibilities as you advance.

Some of these rate training manuals will be useful to you when you are preparing to meet the occupational qualifications for advancement to MM1 and MMC. They are discussed briefly in the following paragraphs.

Machinist's Mate 3 & 2, NAVEDTRA 10524. Satisfactory completion of this training manual is required for advancement to MM3 and MM2. If you have met this requirement in an earlier edition, you should thoroughly review the latest revision. Much of the information given in this edition of *Machinist's Mate 1 & C* is based on the assumption that you are familiar with *Machinist's Mate 3 & 2.*

The rate training manuals prepared for other engineering and hull ratings will be most useful in helping you and your personnel learn about the duties of those who work nearby. Some examples of ratings similar to yours are Boiler Technician, Engineman, and Machinery Repairman.

Other NAVEDTRA Publications

The following books will be useful as you prepare for advancement to MM1 and MMC:

- *Tools and Their Uses*, NAVEDTRA 10085-B. This training manual is not specifically required for advancement in the Machinist's Mate rating. However, it contains a lot of useful information on the care and use of all types of hand tools and portable power tools commonly used in the Navy.

- *Blueprint Reading and Sketching*, NAVEDTRA 10077. It is a good idea to review this book before you take the advancement examination.

- *Mathematics*, volume 1, NAVEDTRA 10069, and *Mathematics*, volume 2, NAVEDTRA 10071. If you need to brush up on your mathematics, these two training manuals may be helpful. Volume 1, in particular, contains basic information for using formulas and for making simple computations. The information in volume 2 is more advanced. However, there will be times when you will need it, especially when you are called upon to advise others.

- *Engineering Administration*, NAVEDTRA 10858. This book will help you become familiar with the duties and responsibilities of the engineering officer during all phases of ship operation.

- *Principles of Naval Engineering*, NAVEDTRA 10788. This book will help you gain general and theoretical knowledge of the ship's engineering plant and hull.

Most rate training manuals and officer texts are used as the basis for correspondence courses. Credit for the completion of a mandatory training manual is earned by passing the correspondence course that is based on that training manual. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training manuals. A correspondence course helps you to master the information given in the training manual or text. It also gives you a good idea of how much you have learned.

NAVSEA PUBLICATIONS

A number of publications issued by the Naval Sea Systems Command (NAVSEASYSCOM) will be of interest to you. While you do not need to know everything in these publications, you should have a general idea of their contents so that you can find information as you need it.

Naval Ships' Technical Manual (NSTM)

The *Naval Ships' Technical Manual* is the basic doctrine publication of the Naval Sea Systems Command. Chapters are usually kept up to date by yearly revisions or less frequently where yearly revisions are not necessary. Some chapters require intra-year changes. In these cases, an intra-year edition may be distributed. If not, then a NAVSHIPS notice is distributed as a temporary supplement pending issue of the new edition.

Chapters in *Naval Ships' Technical Manual* of particular importance to Machinist's Mates are referenced in this training manual. Chapter 001, general 15th revision, contains a list of all chapters in the manual.

NAVSEA Journals

The *Deckplate* is a monthly publication that contains interesting and useful articles on all aspects of shipboard engineering. It provides information on the design, construction, conversion, operation, maintenance, and repair of naval vessels and their equipment. This magazine is particularly useful because it previews information that will come out later in the *Naval Ships' Technical Manual.*

Manufacturers' Technical Manuals

Manufacturers' technical manuals are furnished with most machinery units and many items of equipment. They are valuable sources of information on construction, operation, maintenance, and repair. Most manufacturers' technical manuals are given a NAVSEA number.

Drawings

Some of your work as an MM1 and MMC requires an ability to read and work from mechanical drawings. You will find information on how to read and interpret drawings in *Blueprint Reading and Sketching*, NAVEDTRA 10077.

In addition to reading drawings, you must also know how to locate the drawings you need. For some purposes, the drawings included in the manufacturer's technical manuals may give you

the information you need. However, you will often find it necessary to consult the onboard drawings. The onboard drawings are known as ship's plans or ship's blueprints, and they are listed in an index called the ship drawing index (SDI). The SDI lists all working drawings that have a NAVSHIPS drawing number, all manufacturers' drawings designed as certification data sheets, equipment drawing lists, and assembly drawings that contain detail drawings.

Engineering Handbooks

For certain types of information, you may need to consult various kinds of engineering handbooks. Some examples are the mechanical engineering handbooks, the piping handbooks, the machinery handbooks, and other handbooks that provide detailed specialized technical data. Most engineering handbooks contain a great deal of technical information, much of it arranged in charts or tables. One example is the *Ships's Information Book* (SIB). To make the best use of all engineering handbooks, use the table of contents and index pages to find the information you need.

SUMMARY

This chapter has dealt with the structure of the Machinist's Mate rating including the naval and occupational standards that apply to MM1 and MMC. It has covered sources of information that you need to do your job and advance in rating. Finally, it covered suggested ways of finding and using information.

If you feel that some of your thinking on any of these subjects is still unclear, go back now and review the parts that apply. Write to Naval Education and Training Program Development Center (Code 312), Pensacola, Florida 32509-5000, if you have any problems with the information in this book.

NUMBER	OCCUPATIONAL STANDARD	CHAPTER
MACHINIST'S MATE FIRST CLASS (MM1)		
31 MECHANICAL MAINTENANCE/OPERATION PROPULSION		
31432	PERFORM FINAL INSPECTION TO REPORT ENGINEROOM READY TO ANSWER BELLS	10
31443	SUPERVISE SPLIT PLANT OPERATION	10
35 ADMINISTRATION		
35122	PREPARE MAIN ENGINE RECORD SHEETS	11
35125	RECORD FULL POWER AND ECONOMY TRIAL DATA	10
*35708	PREPARE MONTHLY SUMMARY OF ENGINEERING DATA	11
44 TRAINING		
44017	INSTRUCT PERSONNEL IN OPERATION, MAINTENANCE AND CASUALTY CONTROL PROCEDURES	2, 10
44018	CONDUCT CASUALTY CONTROL DRILLS	10
46 PUBLICATIONS		
*46022	MAINTAIN TECHNICAL AND MAINTENANCE MANUALS	1
50 MAINTENANCE PLANNING AND QUALITY ASSURANCE		
*50633	CONDUCT QUALITY ASSURANCE INSPECTIONS	3, 11
*50877	PREPARE PLANNED MAINTENANCE SYSTEM (PMS) SCHEDULES	11
*50978	REVIEW COMPLETED MAINTENANCE DATA SYSTEM (MDS) FORMS	12
54 LOGISTICS SUPPORT		
*54007	PREPARE MATERIAL DEFICIENCY REPORTS	12
*54191	SUBMIT COSAL ALLOWANCE CHANGE REQUEST	12

*Denotes change.

Figure 1-1.—Occupational standards.

NUMBER	OCCUPATIONAL STANDARD	CHAPTER
MACHINIST'S MATE FIRST CLASS (MM1)—CONTINUED		
94 MECHANICAL MAINTENANCE		
94082	PERFORM HYDROSTATIC TESTS	5, 7, 8
*94118	PERFORM CORRECTIVE MAINTENANCE ON COMPONENTS OF REDUCTION AND TURNING GEARS	3
*94119	PERFORM CORRECTIVE MAINTENANCE ON HIGH PRESSURE STEAM VALVES	11
*94375	TEST OPERATION OF GOVERNORS AND OVERSPEED TRIPS	4, 6
CHIEF MACHINIST'S MATE (MMC)		
31 MECHANICAL MAINTENANCE/OPERATION PROPULSION		
31164	SUPERVISE FULL POWER AND ECONOMY TRIALS	10
*31458	EVALUATE OPERATIONAL TEST RESULTS	4, 5, 6, 7, 8, 9
*31459	EVALUATE OPERATIONAL DEFICIENCIES	4, 5, 6, 7, 8, 9
*31463	MONITOR RESULTS OF MAINTENANCE AND OPERATIONAL TESTS	2, 4, 5, 6, 7, 8, 9
*31475	SUPERVISE START-UP OF STEAM PROPULSION PLANT MACHINERY	1, 2, 3, 4, 5, 6, 7
35 ADMINISTRATION		
35130	ASSIGN PERSONNEL TO WATCH STATIONS	10
*35465	SUPERVISE INSPECTION AND SURVEY OF EQUIPMENT	12
35704	SUPERVISE MAINTENANCE OF LOGS AND RECORDS	10
35706	REVIEW OPERATING LOGS AND RECORDS	10
35707	PREPARE SHIP TRIAL REPORTS	11
35711	PREPARE CASUALTY REPORTS (CASREPS), CASUALTY CORRECTION REPORTS (CASCORS) AND SITUATION REPORTS (SITREPS)	12
*35839	MAINTAIN CONTROLLED EQUIPAGE RECORDS	12

*Denotes change.

NUMBER	OCCUPATIONAL STANDARD	CHAPTER
CHIEF MACHINIST'S MATE (MMC)—CONTINUED		
48 MATERIAL CASUALTY CONTROL		
48036	SUPERVISE CASUALTY CONTROL PROCEDURES	10
50 MAINTENANCE PLANNING AND QUALITY ASSURANCE		
50901	REVIEW SHIP TO SHOP MAINTENANCE PROGRESS REPORTS	12
50902	VERIFY COMPLIANCE WITH QUALITY ASSURANCE PROCEDURES	12
50903	VERIFY ACCURACY OF THE PMS PACKAGE	11
*50962	VERIFY ACCURACY OF SHIP'S DRAWINGS, SYSTEM DIAGRAMS AND WRITTEN SYSTEM/EQUIPMENT OPERATING PROCEDURES	11
*50969	REVIEW PLANNED MAINTENANCE SYSTEM (PMS) SCHEDULES	11
*50979	PERFORM CASUALTY ANALYSIS	11
54 LOGISTICS SUPPORT		
54705	ESTIMATE TIME AND SUPPORT FOR REPAIR OF PROPULSION EQUIPMENT	11
54711	POST CHANGES TO SECAS AND SUBMIT REPORTS	12
54713	SCREEN REQUISITIONS	12
94 MECHANICAL MAINTENANCE		
*94023	PERFORM INTERNAL INSPECTION OF MAIN PROPULSION TURBINE AND REDUCTION GEARS	2, 3
*94025	INSPECT STRUCTURAL INTEGRITY OF TANKS AND VOIDS	11
94088	SUPERVISE MAINTENANCE ACTIONS	2, 4
94089	INSPECT WORK AREAS, TOOLS AND EQUIPMENT	2, 3, 4, 6
94090	SUPERVISE TAKING OF READINGS AND TESTS	10
98 ENVIRONMENTAL POLLUTION CONTROL		
98006	SUPERVISE OIL SPILL CONTAINMENT AND COLLECTION DRILLS AND ACTIVITIES	11

*Denotes change.

Figure 1-1.—Occupational standards—Continued.

CHAPTER 2

TURBINES

For a ship to answer bells and meet commitments, the turbines must be available for propulsion at all times. If propulsion equipment, including turbines, is to be ready at all times, it must receive the best of care in operation, maintenance, and repair.

This chapter presents selected information on the operation, maintenance, and repair of the most common types of main turbines; it is meant only as basic training. You should always use technical manuals and detailed drawings when you inspect and repair turbines. Whenever practical, follow manufacturer's recommendations on operation, methods of assembling, and fitting of parts. Carry out all periodic inspections and preventive maintenance according to the planned maintenance system and the applicable equipment technical manuals.

TURBINE DESCRIPTION

The turbines used in naval ships differ with respect to power level requirements, fuel economy, and the extent of operational capability when there is some turbine derangement. They have evolved to the point that they now maintain high turbine efficiency in cruising and full-power modes. The five major types of turbines used in naval ships are described below:

1. Type I (single-casing unit)—The Type I propulsion unit consists of one or more ahead elements, each contained in a separate casing and identified as a single-casing turbine. Each turbine delivers approximately equal power to a reduction gear.

2. Type II-A (straight-through unit)—The Type II-A propulsion unit is a two-element straight-through unit. It consists of two ahead elements: a high-pressure (HP) element and a low-pressure (LP) element. The HP and LP elements are contained in a separate casing and are commonly known as the HP and LP turbines, respectively. The turbines deliver power to a single shaft through a gear train and are coupled separately to the reduction gear. Steam is admitted to the HP turbine and flows straight through the turbine axially without bypassing any stages. (There is partial bypassing of the first row of blades at high power.) The steam is then exhausted to the LP turbine through a crossover pipe.

3. Type II-B (external bypass unit)—The Type II-B propulsion unit is similar to the Type II-A. The exception is a provision to bypass steam around the first stage or the first several stages of the HP turbine at powers above the most economical point of operation. Bypass valves are located in the HP turbine steam chest, with the nozzle control valves.

4. Type II-C (internal bypass unit)—The Type II-C is similar to the Type II-A. The exception is a provision to bypass steam from the first-stage shell around the next several (one or more) stages of the HP turbine at powers above the most economical point of operation. Bypass valves and steam connections are usually integral with the HP turbine casing. However, in some installations, the valves are separate and bolted directly to the casing, with suitable connecting piping between the first-stage shell and valve to the bypass belt.

5. Type III (series-parallel unit)—The Type III propulsion unit consists of three ahead elements, known as the HP element, intermediate pressure (IP) element, and LP element. The HP and IP elements are combined in a single casing and known as the HP-IP turbine. Steam is admitted to the HP-IP turbine and exhausted to the LP turbine through a crossover pipe. For powers up to the most economical point of operation, only the HP element receives inlet steam. The IP element is supplied in series with steam from the HP element exhaust. At powers above this point of operation, both elements receive inlet steam in a manner similar to that in a double-flow turbine. During ahead operation, no ahead blading is bypassed. Series-parallel units are being used on some of the more recent naval combatant vessels.

All of these types of turbines contain an astern element for emergency stopping, backing, and maneuvering. An astern element is located in each end of a double-flow LP turbine.

CONTROLS

As Machinist's Mates, we must be able to adjust the quantity of steam flow to control the turbine through its power range. A system of nozzle control valves performs this function. The nozzle control valve transfers steam from the turbine chest to the inlet area of the first-stage nozzles in the quantity required to produce the desired power level. The methods of controlling these valves differ on various turbines. One example is the cam and bar lift method (fig. 2-1), which controls speed by varying the number of nozzle valves that are opened. This arrangement consists of a horizontal bar with a series of vertically bored holes, one for each control-stem valve. The bar itself is supported and moved in a vertical plane by two lift rods. The nozzle valves, commonly known as poppets, hang on a button that rests on top of the valve seat. In the closed position, the valves are supported by their valve seats and held down by steam pressure. The valve stems are of varying lengths. Therefore, the valves are opened sequentially by the bar as it lifts. The shortest stem valve will lift first, then the longer ones. The bar is lowered by a spring return and closes the valves. The cam, usually connected to a remotely located throttle handwheel, raises and lowers the lifting bar as the throttle wheel is opened and closed.

OPERATION OF TURBINES

Each ship should have a detailed procedure for starting up the main propulsion turbines.

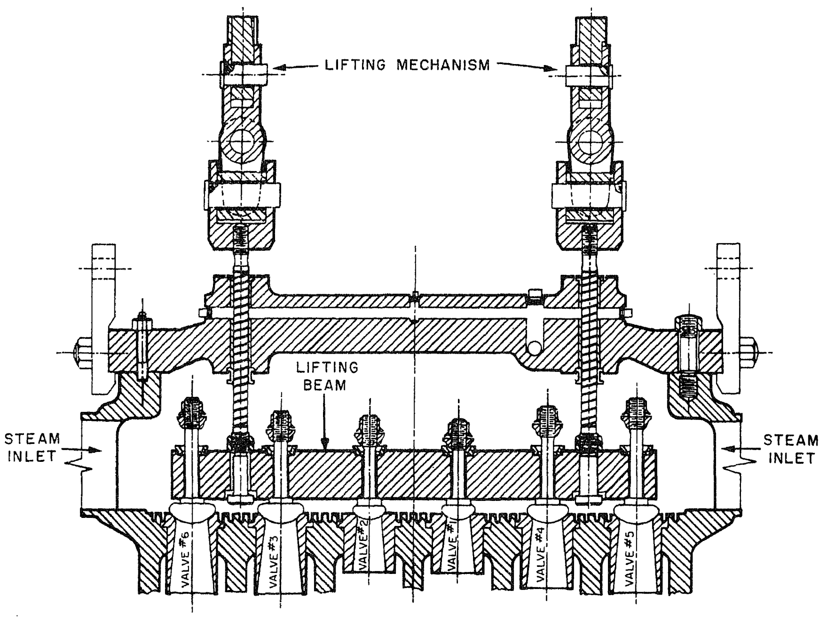

Figure 2-1.—Arrangement of nozzle control valves.

These procedures can be found in the manufacturer's technical manual and the engineering operational sequencing system (EOSS).

The simple fact that turbine materials expand when heated has an influence on the design. Since most of the clearances are specified in thousandths of an inch, warm-up of the turbine becomes critically important. Here are some of the most important procedures to be used for proper warm-up:

1. Heat the lube oil to a minimum of 90 °F and establish the lubricating-oil system pressure.
2. Turn the turbine rotors with the turning gear until just before the steam is admitted to the turbine chest.
3. Maintain a reduced vacuum.
4. Spin the engine, alternately ahead and astern, every 2 minutes.

Follow these procedures and holding conditions for the times specified. In this way, turbine metal temperatures will be brought uniformly as close to operating temperature as heat sources (lube oil, gland seal steam, and small quantities of main steam) will allow. A start-up after an improper warm-up can cause any number of problems. Some of the most common are excessive thermal stress, rotor-to-casing rubs from differential expansions, or excessive vibration from a bowed rotor.

To minimize the amount of bowing at the rotors, keep turning them slowly during the warming or cooling of the turbines. You can use the turning gear or spin the rotors at slow speeds by alternately opening and closing the ahead and astern throttle valves. Usually, a combination of both methods is used.

To secure the turbines, close the throttle that admits main steam to the turbine; open the drains; and shut down the oil, gland, and vacuum systems. The equipment manuals and the EOSS explain the order in which these should be done and the amount of time various systems should be left in operation during cool-down periods.

LUBRICATION OF TURBINES

One of the more important factors in the operation and maintenance of main turbines is an adequate supply of lube oil having the correct physical and chemical qualities. The main lube-oil system provides a continuous supply of oil to the turbine and reduction gear bearings. It is provided at the best temperature for proper lubrication of the bearings and to remove heat.

Under normal operating conditions, the temperature of the oil leaving the lube-oil cooler should be between 120 °F and 130 °F. The outlet temperature of the bearing should be between 140 °F to 160 °F but not greater than 180 °F. The maximum temperature rise allowable in the bearing is 50 °F, even though this maximum rise may result in a temperature less than the 180 °F maximum.

Bearing temperatures are indicated by the temperature of oil flowing from the bearings. A thermometer fitted in each bearing as near as possible to the point from which the oil drains from the bearing shell registers the temperature of the oil.

The bearings and gears require a high-grade mineral oil (2190 TEP). The oil is kept free from water and impurities by the lube-oil purifier and the settling tank. To keep a continuous check on the condition of the lube oil, follow a routine procedure of taking oil samples. Test the lube oil at regular intervals as specified in PMS. To determine the neutralization number, flash point, viscosity, and other physical or chemical properties that govern the effectiveness of oil as a lubricant, submit a sample of lube oil to the U.S. Navy Petroleum Testing Laboratory. When operating the turbines, do not rotate them if they have a lube-oil temperature below 90 °F. The lube-oil purifier should be operated at least 12 hours a day when the ship is underway.

You must stay on the alert for signs that equipment or systems are about to fail. Your sight and hearing, helped by reference to operating instruments and logged data, provide the normal means to evaluate the condition of the propulsion system. Investigate promptly any deviation from the normal. Prompt and proper action can usually confine a casualty to a specific piece of equipment or system.

Report any casualty to the supervising watch stander immediately. This ensures that the impact of the casualty on the system or the entire ship can be properly assessed and that appropriate action can be taken.

FAILURE OF LUBE-OIL SUPPLY

Loss of lubrication will have an almost immediate harmful effect on the turbine journal and thrust bearings. The lube oil takes away heat generated at the bearing and reduces friction between moving and stationary load-bearing surfaces. Therefore, reducing or stopping the oil flow causes rapid overheating, which will eventually cause the babbit to melt. The turbine bearings are among the most sensitive to overheating because of their high running speeds.

In many instances, loss of lube-oil pressure has been caused by improper operational procedures rather than by material failure. All concerned personnel must understand that even a momentary loss of lube-oil flow will cause localized overheating and probably slight warping of one or more bearings. You must thoroughly understand the precautions and procedures used to prevent low lube-oil pressure. You must also be trained in a sound casualty control procedure, in case this condition occurs.

A loss of lube-oil pressure may be caused by a failure of the power supply to the main lube-oil pumps, either steam or electric. The lube-oil system may fail because it is clogged by rags, dirt, or other foreign matter. Lube-oil pressure may also be lost because piping or an operating pump failed or because a standby pump did not start.

The low-lube-oil alarm should be tested and adjusted as required to ensure that it will warn operating personnel of a low lube-oil pressure. To ensure that a failure of the lube-oil supply is handled properly, you should ensure all personnel are trained in the casualty procedures outlined in the engineering operating casualty control (EOCC) books.

HOT BEARINGS

During turbine operation, temperature is the sole criterion available to the operator for judging the conditions of individual bearings. Watch standers should monitor and log temperatures periodically. This ensures that any tendency of bearings to overheat can be detected early and appropriate action can be taken.

Bearing temperatures increase with speed and a change in speed. There is a normal temperature range over which the bearings operate. To ensure proper operation of the turbine bearings, you should establish a temperature-versus-speed standard for reference. The temperature of oil supplied to the bearings ranges between 120°F and 130°F, and comparisons should be made on the basis of equal inlet temperature.

If a bearing temperature increases above the normal running temperature, check the system oil pressure to ensure a normal value. Also check the temperature of the oil from the cooler to ensure that the oil temperature is in its normal operating range. Any bearing temperature increase above normal operating temperature is considered a hot bearing. You should begin casualty control procedures according to the EOCC book.

If the oil temperature through the bearing continues to rise, either to a maximum temperature rise from inlet to outlet of 50°F or to a maximum temperature on the outlet thermometer of 180°F, you have an uncontrollable hot bearing. Stop the propulsion shaft for further investigation.

ABNORMAL NOISE OR VIBRATION

Propulsion turbine rotors are precisely manufactured components. They are balanced to the degree that vibration is almost nonexistent. However, a moderate increase in the vibration level is expected because of the rotor's attachment to the driven unit and because of changes in operating temperatures.

Turbine rotors should not remain at rest for more than 5 minutes while steam, including gland seal steam, is being admitted to the turbines. Roll the turbine with turning gears before admitting steam to the turbine glands. Maintain a vacuum of 25 inches of mercury during warm-up to allow for even heat distribution.

Be sure the glands are properly sealed in order to maintain a vacuum on the turbine. Air leaking in along the shaft could cause distortion of the shaft and rotor. Take extreme care to warm up the turbine properly. Otherwise, serious damage may be done.

If the turbine is in operation and suddenly begins to vibrate abnormally, look for any one of the following problems:

- Water in the turbine
- Bearing failure
- Bent or broken propeller blades
- Unbalance because of broken or missing turbine blades
- Rubbing of blading labyrinth packing or oil seal rings
- Bowed rotor
- Excessive differential expansion between rotor and casing
- Loss of flexibility in coupling between turbine and reduction gear
- Change in alignment of turbine to reduction gear

If you hear a rumbling sound from the turbine when it begins to vibrate, the trouble is probably caused by water or foreign matter in the turbine. Water in the turbine casing may be caused by either boiler priming or improper casing and steam line drainage. Immediately slow down the turbine until the abnormal vibration disappears. If the vibration still exists after you slow down the turbine, correct the boiler operation, check the casing and HP drains, shut down the turbine, and inspect the interior of the turbine at the earliest opportunity.

When bearing troubles occur, stop the turbine as soon as practical to prevent damage to the turbine blading. Inspect the bearings and replace or repair as necessary. Determine the cause of the trouble and take appropriate steps to prevent similar troubles from recurring.

Rubbing of shaft packing or oil seal rings will cause the shaft to overheat in the rubbing area because of friction. The shaft will start to show heating discoloration. When this happens, make an immediate inspection to determine the cause of the trouble. If defective bearings are found, replace them. A bowed rotor can be straightened by operating the turbine at low speeds. The shaft packing or oil seals may require refitting or renewal to give proper clearances.

When rubbing of turbine blading occurs, the cause will probably be a bowed rotor, a defective thrust bearing assembly, a wiped journal bearing, foreign material inside the casing, or differential expansion of the turbine rotor and casing. When a rubbing noise in a turbine is heard, stop the turbine immediately and determine the cause.

Foreign matter may enter a turbine casing through a defective steam strainer or because of improper protection of a turbine that has been opened for inspection or repair. When any part of a turbine has been opened, use the greatest care to prevent the entry of foreign matter. Never leave inspection plates off overnight or for any length of time unless the openings are well covered. Before reassembling a turbine after it has been opened, make a very careful examination of the rotor and the interior of the casing for any articles left behind. Make an examination before the rotor is lowered into place and another before the casing cover is lowered into place.

Another cause of vibration is bent or broken propeller blades. Normally, this condition is first indicated by excess vibration of the main shaft and by a lesser vibration in the main reduction gears. When these conditions exist, slow the main turbines until the noise and vibration stops or is within safe limits. Make an immediate inspection to determine the cause of vibration.

If vibration of the turbine is caused by bent or broken turbine blading, the turbine should not be used until effective repairs can be made by experienced personnel.

TURBINE MAINTENANCE

We must have maximum operational reliability and efficiency of steam propulsion turbines. This requires a carefully planned and executed program of inspections and preventive maintenance and strict adherence to prescribed operating instructions and safety precautions. Proper maintenance procedures usually prevent abnormal conditions.

The interior of main turbines should be inspected through available inspection openings. Table 2-1 lists maintenance items that should be inspected according to the planned maintenance system. Make the appropriate entries in the engineering log.

MEASUREMENTS AND ADJUSTMENTS

The satisfactory operation of a turbine depends, along with other factors, on the fixing of the proper radial and axial positions of the rotor. The radial position is maintained by the journal bearings, and the axial position by the thrust bearing.

A depth gage micrometer is the quickest means of detecting any change in the relief position of the rotor caused by bearing wear. Take the measurements at each turbine journal bearing without removing the bearing caps. The bearing caps have plugged openings for inserting the depth micrometers.

When a turbine is first installed, take a reading at each bearing with the depth micrometer. Log this reading for reference when you take future readings. Take the readings when the units are cold and the rotors are stationary. Always inspect bearings when the depth gage shows that the clearances have reached the maximum values outlined in the manufacturer's technical manual and the planned maintenance system. When the bearing is opened for inspection, measure the outside diameter of the rotor journal and the inside diameter of the bearing to determine actual oil clearances. The difference between the old and new oil clearance readings will be the amount of bearing wear. The decision to replace the bearing should be based on these measurements and not on the depth gage readings.

The axial position of a turbine rotor is maintained by means of a thrust bearing, usually a Kingsbury type. The installed rotor position indicator is a quick and constant means of checking the axial position of the rotor shaft.

Table 2-1.—Maintenance Items and Purpose

Item	Purpose
Verification of radial and axial position of the rotor by appropriate clearance measurements.	Avoid internal rubs that can make turbine inoperable.
A clean lube oil system and proper lubricant quality and quantity.	Avoid wiping of bearing, scoring of journals and thrust collar, and chemical attack on those and other critical surfaces.
Freedom of control and trip valve mechanisms.	Avoid slow action or hang-up of throttle or trip valves.
Check condition of oil deflectors and waste oil drains.	Avoid ingress of oil into steam system.
Check condition of water drains.	Avoid ingress of water into lubricating oil system, blade erosion, and water slugging.
Check condition of shaft and gland packing.	Avoid blowing steam into engine spaces or pulling air into turbine or condenser.
Check cleanliness of turbine internals.	Avoid ingress of foreign material through access openings or through connected piping, which restricts internal damage (mechanical or chemical).

One way to measure the thrust clearance is to jack the rotor fore and aft while taking readings on a dial indicator to show the total axial movement of the rotor. The thrust bearing must be completely assembled and the upper half of the bearing cap bolted in place while readings are taken. Attach a dial indicator to some fixed point, such as the bearing bracket. Arrange it so that the indicator spindle touches the shaft. Jack the rotor as far as possible in one direction. Make sure that the indicator spindle is just touching the shaft, and set the indicator dial at zero. Jack the rotor fore and aft at least three times, using the average of the readings to determine the thrust clearance. Exert just enough pressure to hold the rotor firmly against the thrust shoes in each direction. Avoid bumping the rotor too hard; this could cause false readings. Do not bar the rotor with the thrust shoes removed; the packing teeth or blade shrouds may be damaged from bumping.

Any large increase in the thrust clearance will allow the clearances between the rotating and stationary blading to decrease. If this problem continues, it will cause rubbing of the parts. When thrust clearance has increased to the maximum value, adjust the thrust to bring it back to its original designed clearance. Use the taper gage to check the clearance between the rotating and stationary blading of the high-pressure and low-pressure turbines.

TURBINE BEARING MAINTENANCE

When you open a bearing, inspect it carefully for ridges and scores. Take oil clearance readings to determine the amount of wear. Note whether or not the babbitt lining has remained anchored to the shell. If the bearing is slightly wiped, you can probably scrape it to a good bearing surface and restore it to service. In this case, the clearance readings of the reconditioned bearing on the originally designed value should be within tolerance.

THRUST BEARING REPAIR

When trouble occurs or is suspected in a thrust bearing, measure the oil clearance in the bearing before the bearing is disassembled. If the readings are beyond allowable tolerances, disassemble the bearing for inspection.

When it is necessary to disassemble a thrust bearing, make a careful inspection of all parts. If there is slight rusting of the collar surfaces, remove the rust with fine crocus cloth to assure that metal is not removed from the collar. The work should be done slowly and carefully by experienced personnel. Renew the shoes if wear exceeds allowable limits. When taking measurements of the shoes, consult the detailed drawings for the location and design value of such a measurement.

If damaged thrust shoes cannot be reconditioned by the ship's force, send them to a repair activity to be rebabbitted and machined. The radial edges of the shoes should be slightly rounded; otherwise, the sharp edges will tend to scrape the oil film off the thrust collar.

If a thrust collar is badly scored or if deep rust pits cause rapid wear and frequent replacement of shoes, the collar should be repaired. On some turbines, you can remove the thrust collar without lifting the casing and without disturbing the lower half of the forward journal bearing. Removal and installation procedures may be found in the applicable technical equipment manual.

When a thrust collar is to be remachined, the bore should be square with the faces. The faces should be machined flat and smooth, and the thickness should meet the required specifications as stipulated on the blueprint or in the manufacturer's technical manual. The marks left by machining or grinding must be removed by lapping.

When the thrust bearing has been reassembled and the oil clearance taken, compute the thickness of the shim to be added. Take, for example, a thrust bearing that has the following clearance specifications: designed clearance 0.010 inch, maximum clearance 0.020 inch, and minimum clearance 0.007 inch. If you get a reading of 0.025 inch, install a shim of 0.015 inch. Never use more than one shim to obtain the proper oil clearance.

An exploded view of a (two-way) six-shoe thrust bearing is illustrated in figure 2-2. An assembled thrust bearing and a lower inner casing are shown in figure 2-3. For more technical information concerning thrust bearing

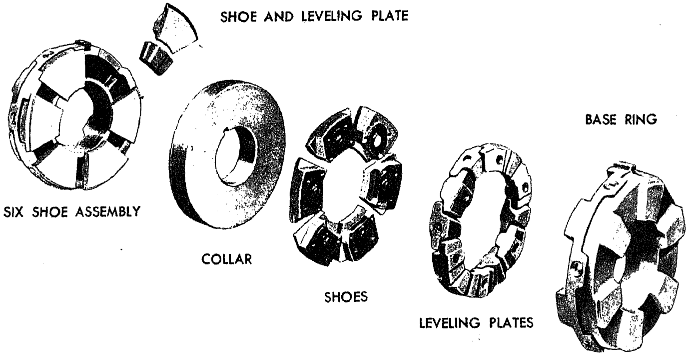

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Figure 2-2.—Small double (two-way) six-shoe thrust bearing.

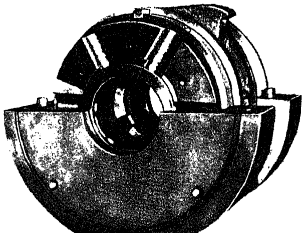

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Figure 2-3.—Thrust bearing (assembled) and lower inner casing.

repairs, consult your manufacturer's technical manual and *Naval Ships' Technical Manual*, chapter 231, "Propulsion Turbines."

Journal Bearing Repair

Journal bearings need not be disassembled periodically for inspection. However, if a maintenance requirement card (MRC) action discloses an out-of-tolerance measurement or if an operational difficulty develops, disassembly and inspection may be necessary. When an inspection becomes necessary, make a detailed visual examination of the various bearing surfaces and take appropriate wear measurements.

Bearing wear would be almost eliminated under ideal conditions. However, some journal-to-bearing rubbing contact is made on each start. A properly installed bearing that has been in service for some time will usually display a worn or polished area centered in the lower half of the bearing.

Discoloration of bearing surfaces almost always indicates lubrication problems. The moisture in the oil and operation under high temperatures can produce a tin oxide coating on the bearings. The coating is very hard and builds up to reduce bearing clearance. Thin castings can normally be scraped off without exceeding oil clearances.

Bearings should be disassembled only with justification because of the dangers of improper reassembly. If disassembly is necessary, it is important that the work be done, or closely supervised, by qualified personnel.

Replacement of Journal Bearings

When a bearing surface is scored, uneven, considerably worn, wiped, or burned out, or if

the metal is loose, it must be rebabbitted or replaced. The detailed procedure for replacing turbine bearings will vary somewhat for different sizes and types of turbines. For those types in which the upper and lower half of a bearing may be accidentally interchanged or the axial position reversed, take care to properly mark all parts while the bearing is being disassembled. A bearing improperly installed will not receive adequate lubrication. A typical turbine bearing is shown in figure 2-4.

When you are getting a spare bearing ready for installation, clean and inspect it carefully. Bolt or clamp the two bearing halves together and measure the inside diameter of the bearing with an inside micrometer. The inside diameter of the bearing should equal the outside diameter of the journal plus the designed oil clearance. You can find the dimensions for a bearing in the manufacturer's technical manual or the applicable blueprints. Ensure that a bearing that has been rebabbitted complies with dimensional specifications. Thermal distortion from heating and cooling the bearing shells during rebabbitting often results in dimensional variations of the spherical contour.

After you remove the bearing cap and the upper half of the bearing, lift the weight of the rotor with a jacking device (fig. 2-5). Lift the rotor vertically about 0.005 inch, as determined by a dial indication reading. This permits the lower half of the bearing to be rolled out. Lifting the rotor too much will damage the shaft packing, and the

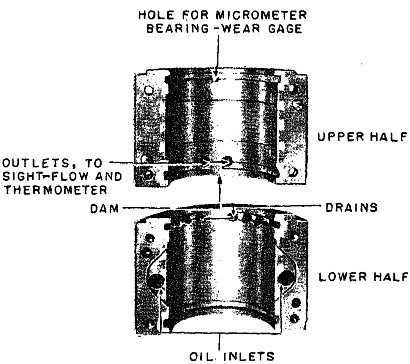

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Figure 2-4.—A typical propulsion turbine journal bearing.

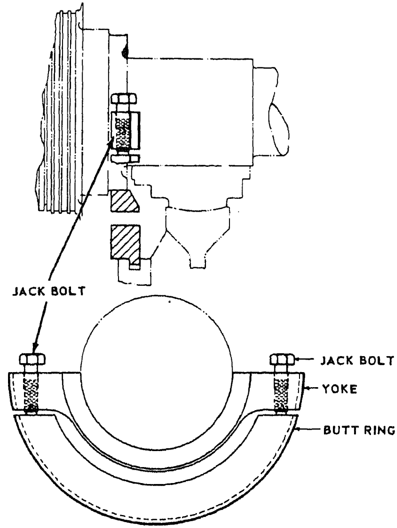

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Figure 2-5.—Special jack used to remove the lower half of a journal bearing.

bearing half might bind. Before removing the lower half of the bearing, ensure that the thermocouples are removed and the RTEs are disconnected (if applicable). When the lower half of the spare bearing is installed, remove the jack and reassemble the bearing. Then take a depth gage reading to reestablish a constant.

When a defective bearing has been replaced by a spare, the old bearing should be rebabbitted as soon as possible if it is a reusable type. The usual procedure is to have a repair ship or shipyard rebabbitt and machine the bearing. The appropriate blueprints or manufacturer's technical manual will have to be furnished to the repair activity. These sources contain the necessary detailed information concerning the bearing dimensions.

NOZZLE CONTROL VALVE REPAIR

The nozzle control valves for the main high-pressure turbines normally will operate for a long period of time without maintenance or repairs.

However, they are subjected to high steam pressures and temperatures, and in time they will require repairs.

One of the more common troubles with nozzle control valves is the leakage of steam between the valve seat and disk. If leakage is suspected, visually inspect the contact area of each valve for steam cuts, pits, and erosion. Clean the contact area of the valve disk and its seat and then check by bluing each valve. If the valve disk does not make a good contact with its seat, do not use the valve disk to lap the seat. If you do, you will make a flat spot on both the valve and seat and destroy the spherical surface of the valve. Figure 2-6 shows an enlarged section of one type of nozzle control valve.

Most valve seats have flat, angular surfaces at the line of contact with the spherical surfaces of the valve disks. Resurface the valve seat using the following suggested method: Turn a cast-iron cone with an angle the same as the valve seat angle, as shown in figure 2-7. Leave a tip on the upper end of the cone. It can then be held in and turned by hand or driven by an air motor if considerable metal is to be removed. With this cone and some grinding compound, you can resurface the flat angle of the valve seat. Use a mechanical guide to keep the lap square with the seat and take care not to grind off any more metal than is necessary. The surface of the valve may not be spherical because of pits or wear. If so, place the valve in the lathe and polish it with emery cloth and oil until the surface is smooth and there is less than a 0.0005-inch runout. In this way the valve disk will maintain a spherical surface and seat tightly even if slightly out of line. Badly cut or damaged seats and disks should be replaced rather than reconditioned.

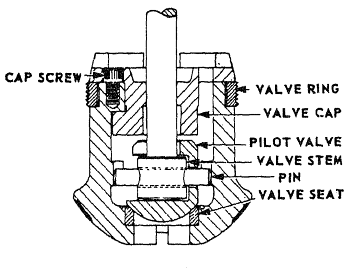

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Figure 2-6.—Section of a nozzle control valve (pilot valve details).

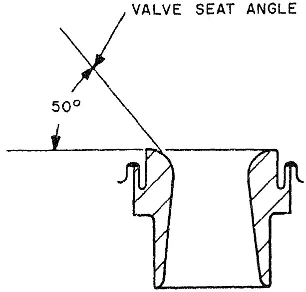

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Figure 2-7.—Valve seat angle.

SHAFT PACKING

Because the main turbine rotor must penetrate and turn with respect to the casing and because internal pressures differ from atmospheric pressure, sealing is required to prevent leakage. Shaft packing in conjunction with the gland seal system keeps steam from leaking out of, or keeps air from leaking into, the turbine. The type used in modern propulsion turbine design is labyrinth packing.

Labyrinth packing rings may experience rubs during turbine operation. They are caused by a misalignment of the rotor and the condition of the packing. These rubs increase the packing clearance, which will cause some loss of turbine operating efficiency and economy. Therefore, packing clearances should be maintained within the minimum and maximums specified in the manufacturer's instruction book. This will ensure the best turbine performance.

Worn labyrinth packing should be replaced. However, if spare rings are not available, you can repair the packing by using a chisel

these tools as indicated in the figure. Strike the chisel with a hammer and then advance around the periphery of the packing a trifle less than the tool's width. Take care that each new position of the chisel overlaps the preceding position. This procedure increases the height of the tooth and draws it out to its original featheredge. Continue drawing out each tooth to give the packing clearance specified on manufacturer's drawings or in manufacturer's technical manuals.

GLAND SEAL SYSTEM

In the discussion of shaft packing, we pointed out that packing limits the steam or air flow to small quantities, but it does not cut off the flow completely. The gland seal system includes supply and leak-off sections. It provides the positive control required to keep steam from leaking out to the engine space and/or to keep air from leaking into the main condenser through the turbine casings.

The system can be, and usually is, automated by use of pressure-regulating valves. These valves hold supply pressure over a narrow pressure range; they use one valve to supply steam when pressure is below a set point and another valve to dump steam when pressure is above the set point.

The entire gland seal system, with the exception of the supply and dump valves, is nearly maintenance free. Maintain the supply and dump valves according to the manufacturer's technical manual.

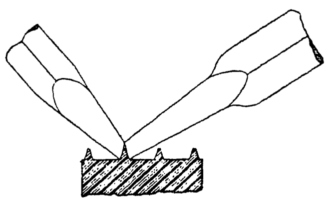

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Figure 2-8.—Restoring the height of labyrinth packing lands.

CASING AND ROTOR

Only a limited number of internal turbine parts can be inspected without lifting the turbine cover or breaking high-pressure joints. Two of the most common occasions for removing turbine covers are to inspect internals prior to overhaul and when operating conditions suggest internal damage. A request to lift a turbine cover must be for a cause other than accumulated time or operating hours.

Make a request to lift casings only when there is knowledge or strong suspicion of internal damage or hazards. Before you make such a request, first try all other means, such as inspections and diagnosis.

Regulation for Lifting Turbines

There are two situations that deal with lifting turbines. The first situation occurs when there is knowledge or suspicion of internal damage and a request to lift is made. In this case, you should get technical determination of the necessity to disassemble the casing directly from Naval Sea Systems Command (NAVSEA) or Naval Ships Systems Engineering Station (NAVSSES). Forward all correspondence regarding approval to disassemble to NAVSEA and NAVSSES for approval.

The second situation occurs 3 months prior to each regular overhaul. At that time, submit a report to the type commander concerning the condition of each propulsion turbine. Consult the *Naval Ships' Technical Manual*, chapter 231, for the information required in the report.

In both situations, direct recommendations to disassemble the turbine or to perform additional tasks or inspections to the type commander, who will make the final authorization to lift casings. The decision will be based on NAVSEA technical evaluations of the conditions reported, schedules, and funds available.

Lifting Casing and Rotor

Whenever turbine casings are lifted for any purpose, take advantage of the opportunity to observe the condition of all nozzles, blading, packing rings, and other internal parts. When practical, make such examinations when adequate facilities are available for necessary repairs that are beyond the capability of the ship's force.

Take all turbine measurements and clearances before and after repairs; maintain a permanent record of these measurements (fig. 2-9 shows the method of checking the rotor position with a taper gage). The record must also include the material condition revealed when the turbine is opened and after repairs are made. Forward a report of these facts to the Naval Sea Systems Command.

Before the casing can be lifted, you must do the following preliminary work: Remove the covers over the flexible couplings between the turbines and the reduction gears. Disconnect and remove sections of the main steam lines. If an HP or LP turbine casing is to be lifted, remove the crossover line between these turbines. Remove drain lines and gland seal lines if necessary. In some turbine installations, you may have to remove obstructions to lifting, such as steam lines and ventilation ducts. It may also be necessary to remove some of the insulation from the turbine.

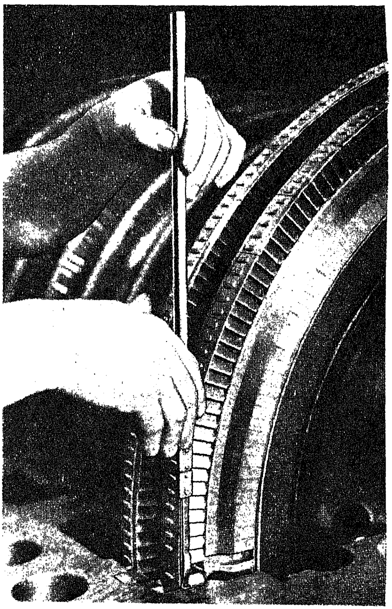

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Figure 2-9.—Using a taper gage to check the position of a rotor.

Provide proper temporary stowage of the piping, valves, nuts, bolts, tools, and other necessary materials either in or out of the engine room. Keep passageways and working areas free of tools and materials being used. Avoid damage to the piping, gauges, gauge lines, lagging, and other material.

After the preliminary work has been completed, remove the turbine-casing horizontal joint bolts. As a rule, you should not remove the vertical joint bolts on the high-pressure turbine except when repairs require the joint to be opened. Most inspection covers have caution plates that call attention to internal bolts or fittings which must be removed. Remove the upper housings and upper halves of main turbine bearings. When disassembling turbine-casing bolts that were tightened by heat, you must apply heat to loosen these bolts. After all the bolts have been removed, break loose the joint by means of jack bolts if necessary.

When the ship is built, pad eyes are welded into the overhead of the engine room for attaching chain falls to lift heavy objects. The manufacturer's technical manual and the ship's blueprints give detailed information on the arrangement, number, and size of the chain falls, wire slings, and shackles to be used to lift any particular piece of machinery. The lifting arrangement for a turbine casing allows the four corners of the upper casing to be lifted in a plane parallel to the flange of the lower casing. Four upper casing guide pins are then installed. If there is a scale on the guide pin, this scale should face outboard where it can be readily seen. The location of the upper casing guide pins is shown in figure 2-10. The guide pins are used to prevent any damage to the turbine blading and shaft packing. As the turbine casing is raised or lowered, handle it in a manner to prevent tilting or swaying so that it will not strike the turbine blading or shaft packing.

When the turbine casing is ready to be lifted, assign personnel to the various jobs and stations. Ten or twelve people are usually needed to raise or lower a main turbine casing. Four people operate the chain falls. Four persons, one at each corner of the turbine casing, take measurement readings from the guide pins. Usually an observer is stationed at each side of the turbine, and one person supervises the entire operation.

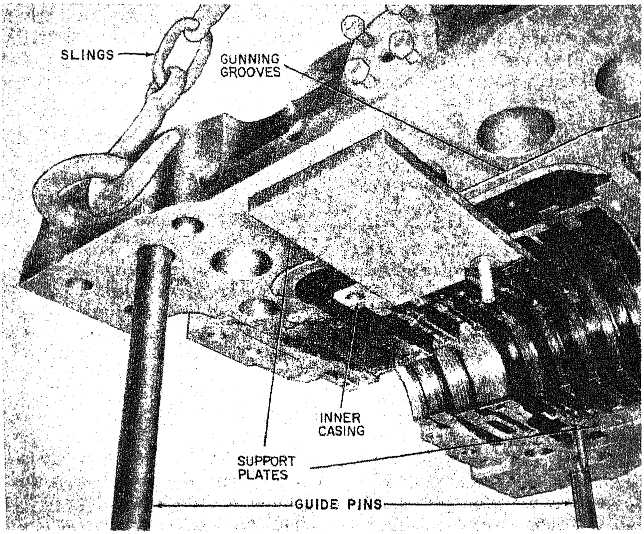

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Figure 2-10.—Lifting or lowering upper casing of a high-pressure turbine.

Raise the casing slowly, keeping uniform heights at the graduated guide pins to ensure that the casing is level and not tilted. The usual procedure is to slowly raise the casing about 1 inch at a time until the upper casing is clear of the rotor. As a safety precaution, insert blocks under the upper casing flange as the casing is raised. When the casing is clear of the rotor, swing it clear of the turbine or secure it in a position above the turbine.

After the casing has been raised to the desired height (not higher than the guide pins) and if it is not to be swung clear, install the four upper casing supports. Have blueprints on hand to show where to install the various turbine supports and guide pieces. Bolt the upper casing support pieces to the upper and lower casing flanges.

The procedure used to lift a turbine rotor is similar to that used to lift the upper casing. Attach four rotor guides to the lower casing of the turbine, as shown in figure 2-11. There are different methods of attaching the wire slings to the turbine rotor. One method, shown in figure 2-11, is used for a small turbine rotor. Another method uses a special lifting yoke and a lifting plate to raise the rotor. In the latter method, the lifting yoke, a form of clamp, is attached to the forward end of the rotor. The lifting plate, a pad eye welded to a plate, is attached to the after face of the shaft coupling flange. Shackles are attached to lifting devices so that chain hoists may be used in lifting the rotor.

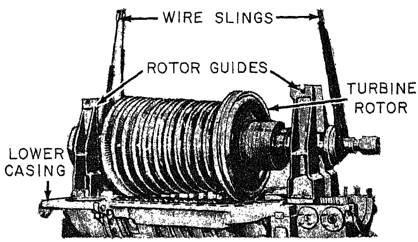

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Figure 2-11.—Lifting a high-pressure rotor.

The rotor guide piece performs two functions: when the rotor is being raised, the guide pieces keep it in a vertical plane passing through the center line of the rotor shaft. Machined surfaces on the inside corners of the rotor guide pieces prevent the rotor from moving forward or aft. The machined surfaces bear with a small clearance against shoulders of the forward and aft ends of the shaft. In many cases, special bushings are attached to the rotor shaft. These bushings are located on the sections of the shaft between the pairs of rotor guide pieces.

After all preliminary work has been completed, slowly lift the turbine rotor from the lower casing. Lift the rotor approximately 1 inch at a time and take measurements at each end to ensure that both ends have been raised evenly. Make adjustments in height as necessary. Repeat this procedure until the rotor has cleared the lower casing.

When a turbine rotor is to be placed in its raised position, you will need special securing devices such as rotor guide saddles, rotor supporting bars, rotor guide tie brackets, and rotor guide spacer bolts. Secure these attachments in place to properly support the weight of the rotor. Use the same procedures to lift and support the high-pressure and the low-pressure turbine rotors.

Rotor Balance

The turbine rotors are carefully balanced, both statically and dynamically. If, under any circumstances, a rotor becomes unbalanced, it must be rebalanced.

Damage to the turbine rotor blading and balance weights will, understandably, cause unbalance of the rotor. You should thoroughly investigate the causes of turbine vibration before having a rotor balanced. *Operating forces should not try to balance a rotor.*

If turbine rotor unbalance is suspected, check the rotor for balance while it is still in the casing. The normal procedure is to notify the type commander, who will determine the repair activity that will conduct the necessary tests and inspections. All turbine rotors must be rebalanced when any of their blading has been renewed or their balance has been altered by repairs.

Reassembling a Turbine

Immediately before you permanently close any opening that has been uncovered, make an inspection to be certain that there are no foreign objects in the turbine and that there are no unsatisfactory conditions. Make a very careful examination of the rotor and the interior of the casing for any articles left behind. Make the examination before the rotor is lowered into place and again before the upper casing is lowered and secured into place.

Maintain strict accountability for tools and parts when working on turbines to ensure that none of these items are left inside. Personnel who work around or inspect uncovered turbines should not carry objects that may fall into the equipment. Secure flashlights with lanyards.

The final inspection should be made by responsible officers, one from the ship and one from the repair activity. Record this inspection and the name of the inspectors in the engineering log.

Sealing a Flange Joint

Before the upper half of the turbine casing is lowered into place, clean the horizontal joints with a solvent. If the solvent fails to clean the flange, mechanical cleaning methods may be necessary. DO NOT use belt sanders, files, or other heavy adhesives. Use only mild scraping material like a crocus cloth.

Apply a thin film of prussian blue to the joint on the upper half casing and to the horizontal joint of internal stationary parts assembled in the upper half casing. Carefully lower the upper half casing onto the lower half. Install all joint studs; lubricate threads and faces of nuts and all washers, and assemble nuts. Cold tighten all studs to approximately one-half the normal operating stud stress to obtain a proper joint check. Disassemble joint nuts and studs and carefully raise the upper half casing; observe the blue contact on the joint of the lower half casing.

If the blue check indicates a poor contact because of local high areas, scrape or stone these areas with a large surface plate (minimum 12 × 18 inches) to obtain a proper blue check. In some cases, the joint may contain eroded areas and grooves caused by steam leakage. To seal these areas and grooves and prevent subsequent leakage, you may find it necessary to apply a small amount of weld. The welding should be done under the supervision of a capable welding engineer and in accordance with approved procedures in *NAVSHIPS' Technical Manual.*

Whenever a casing joint is opened for any reason, a final contact check is required. It is accomplished by taking a red and blue check of the made-up joint. Contact required is as follows:

1. Seventy-five percent contact over the entire joint plus a 1/2-inch minimum continuous contact band inside the bolts and across each pressure section
2. For joints with pumping grooves, 75 percent contact over the entire joint plus a 1/4-inch minimum continuous contact band inside the groove and across each pressure section

The entire joint surface on each casing should be lightly coated with a thin, even film of one of the joint compounds permitted by *NAVSHIPS' Technical Manual*. The use of sheet packing for flange joints is prohibited.

The main horizontal and vertical joints in some turbine casings have a system of grooves in the joint faces for pressure pumping with sealing compound during emergency repairs. These grooves should not be filled with sealing compound during routine overhaul.

Tightening a Flange Joint

Turbine-casing horizontal joint and valve chest-cover bolting must be properly tightened to obtain the clamping force required for satisfactory performance of metal-to-metal steam joints. There are three acceptable measurements in determining the exerted clamping force:

1. The bolt length before and after tightening
2. The torque applied to the nut
3. The advancement of the nut on the bolt thread

Detailed instructions for making up turbine-casing bolting are usually included in the manufacturer's instruction book. If provided, they should be followed.

The preparatory work should consist of clearing all joint studs, nuts, and washers thoroughly. This will remove any previously used thread compound or foreign material. Replace any studs or nuts with damaged threads. Prior to final installation, coat stud threads and nut faces with antiseize compound.

DOCK TRIALS

When a main propulsion turbine has been opened for inspection and repair, the work is not considered complete until a dock trial and a postrepair trial have been satisfactorily completed and any deficiencies found have been corrected.

The engineer officer of each ship may issue instructions for operating the plant during a dock or postrepair trial; however, the general procedure will be as follows:

Before oil is circulated through the lube-oil system, fit muslin bags in the lube-oil strainers. The muslin bags, available at naval shipyards, will prevent very fine particles of dirt from entering the bearings and gears. Start a lube-oil pump and circulate oil through the system. Change the muslin bags often (the interval of time between changes is usually set by the engineer officer). When dirt or other foreign matter is no longer found in the muslin bags, engage the turning gear. Station personnel at various points around the turbine to listen for unusual noises. If no abnormal conditions are detected, consider the turbine ready for a dock trial.

During a dock trial, the ship will remain tied to a pier, and the engines will be turned by steam. The commanding officer usually determines the maximum number of rpm the engines will be permitted to turn. On a ship with two engines, turn one engine in the ahead direction and the other in the astern direction; then reverse the engines.

Warm up the main plants according to the engineer officer's instructions. When the engines are ready to be tested, station the special sea detail. The officer of the deck will shift his watch from the quarterdeck to the bridge, and personnel will be stationed around the turbines to detect unusual noises or other abnormalities. When all stations are manned and the engineering plant is ready, the engineer officer will request permission from the bridge to test the main engines. When the OOD is certain that the area around the fantail is clear of boats, mooring lines, and so forth, he will grant permission to test the main engines. When the main engines have been tested and found satisfactory, the engineer officer will report to the bridge that the main engines are ready for dock trial. One main engine will then be designated to go in the ahead direction and the other in the astern direction. The appropriate orders will be rung up on the engine-order telegraph, and the required rpm will be indicated on the engine revolution indicator. When these orders are

received in the engine room, the engine itself will be turned, by steam, at the indicated rpm. If no abnormal conditions are found, the engineer officer will request an increase in speed. The OOD will order the rpm increased (about 5 rpm each change) until the maximum allowable rpm is reached. If no abnormal conditions are detected, the main engines may be considered ready for a postrepair trial.

Information on postrepair trials is given in a later chapter of this training manual.

SAFETY PRECAUTIONS

Observe the following safety precautions. They apply to the operation, care, and maintenance of main turbines found on Navy ships. For more detailed safety precautions, consult your manufacturer's technical manual and your EOSS books.

1. Do not admit steam to operate the turbine until the exhaust system has been prepared to receive turbine exhaust and the entire system has been properly drained.
2. Do not use auxiliary exhaust steam for warming up the turbines.
3. Be sure that the lubrication system is operating properly before turning over the main engines.
4. Investigate unusual noises at once; operate the turbine cautiously, or stop it, until the cause for the noise has been discovered and remedied.
5. Never fail to investigate any unusual noise coming from a turbine.
6. Do not put way on the ship when turning over the main engines during warm-up.
7. If a turbine vibrates, slow it down, investigate, and locate the cause.
8. Except in an emergency, do not admit steam to the astern turbine until steam to the ahead turbine is secured, and vice versa.
9. Before getting underway, be sure that all steam lines are properly drained of condensate.
10. When steam pressure drops, do not open the throttle to such an extent that the operating pressure of the steam drops to a dangerously low point.
11. Stop the engines immediately if the oil supply fails.
12. No inspection plate, connection, fitting, or cover that permits access to the turbine should be removed without authority of the engineer officer.
13. When turbines are opened, take precautions to prevent the entry of foreign matter. Do not leave the openings unattended.
14. Inspect lifting devices carefully before using them and do not overload them.
15. Avoid air being drawn through turbine glands with the rotor at rest.

CHAPTER 3

REDUCTION GEARS

This chapter contains information on the operation, care, and maintenance of the main reduction gear used on Navy ships. As an MM1 and MMC, you must be familiar with the design and construction details of naval reduction gears. To acquire this information, we recommend that you study this book and review chapter 3 of *Machinist's Mate 3 & 2* and chapter 9420 of the *Naval Ships' Technical Manual.* Details of any particular reduction gear installation will be found in the manufacturer's technical manual.

MAIN REDUCTION GEAR

The main reduction gear is one of the largest and most expensive units of machinery found in the engineering department. It is made up of a number of smaller gears. A main reduction gear that is installed properly and operated properly will give years of satisfactory service. However, a serious casualty to a main reduction gear will either put the ship out of commission or force it to operate at reduced speed. Extensive repairs to the main reduction gear can be very expensive because they usually have to be made at a shipyard.

TYPES OF GEARS

Reduction gears are coupled to the turbine shaft through various arrangements of gears. These gears reduce the speed of the turbine to the speed required by the propulsion shaft and propeller.

Reduction gears are classified according to the number of steps used to reduce speed and the arrangement of the gearing. A combination of gears is called a "train."

The two most commonly used arrangements are the articulated, locked-train, double-reduction gear and the articulated, double-reduction gear. These two types use the double-helical gears.

The articulated, locked-train, double-reduction gear is principally used on combatant-type ships. Figure 3-1 shows the major parts of this type of gear. This gear is used in auxiliary-type ship installations and has replaced the nested-type gear arrangement. It has advantages such as the capability of transmitting higher powers, lower sensitivity to misalignments, and ease of maintenance.

Figure 3-2 shows the articulated, double-reduction gear. This gear has one or more power

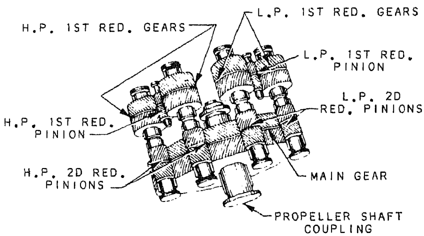

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Figure 3-1.—Articulated lock-train double reduction gear.

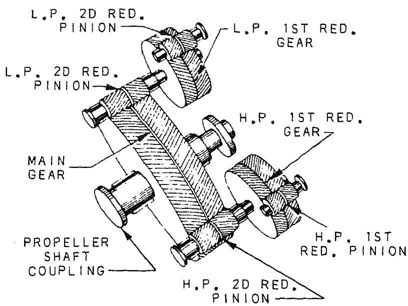

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Figure 3-2.—Articulated double reduction gear.

inputs. It has replaced the nested-type gear arrangement and is usually found in auxiliary-type ships.

OPERATION OF THE MAIN REDUCTION GEAR

The following procedures are essential for the proper operation of reduction gears:

- Supply the required amount of oil to the gears and bearings, and keep the lube oil clean and at proper temperatures. If these requirements are met and if the gears are properly aligned, reduction gears should give reliable service for the lifetime of the ship.

- Lock and unlock the shaft in accordance with the engineering operational sequencing system (EOSS).

- Use the motor-driven turning gears to keep the gears and turbine rotors rotating slowly during cooling-down periods.

- Investigate noises and vibrations and take corrective action.

- Inspect gears in accordance with the planned maintenance system.

LUBRICATION OF GEARS AND BEARINGS

Proper lubrication of reduction gears and bearings is of the utmost importance. The correct quantity and quality of lubricating oil must, at all times, be available in the main sump. The oil must be clean, and it must be supplied to the gears and bearings at the pressure and temperature specified by the manufacturer.

Several conditions must be met for proper lubrication of gears and bearings. The lube-oil service pump must deliver the proper discharge pressure. All relief valves in the lube-oil system must be set to function at their designed pressure. The quantity of oil to each bearing is controlled by an orifice in the supply line; the orifice opening must be in accordance with the manufacturer's instructions, or the supply of oil will be affected. Too small a quantity of oil will cause the bearing to run hot. If too much oil is delivered to the bearing, the excessive pressure may cause the oil to leak at the oil seal rings. Too much oil may also cause a bearing to overheat.

Lube oil must reach the bearings at the proper temperature. If the oil is too cold, one of the effects is insufficient oil flow for cooling purposes. If the oil supply is too hot, some lubricating capacity is lost.

For most main reduction gears, the normal temperature of oil leaving the lube-oil cooler should be between 120°F and 130°F. For full power operation, the temperature of the oil leaving the bearings should be between 140°F and 160°F. The maximum temperature rise of oil passing through any gear or bearing, under any operating conditions, should not exceed 50°F; and the final temperature of the oil leaving the gear or bearing should not exceed 180°F. This temperature rise and limitation may be determined by installed thermometers or resistance temperature elements.

Cleanliness of lubricating oil cannot be overstressed. Keep it free from impurities, such as water, grit, metal, and dirt. Take particular care to clean out metal flakes and dirt when new gears are wearing in or when gears have been opened for inspection. Lint or dirt, if left in the system, may clog the oil spray nozzles; keep the spray nozzles open at all times. Spray nozzles must never be altered without the authorization of the Naval Sea Systems Command.

The lube-oil strainers cannot trap particles of metal and dirt that are fine enough to pass through the mesh. These fine particles can become embedded in the bearing metal and cause wear on the bearings and journals. These fine abrasive particles passing through the gear teeth act like a lapping compound and remove metal from the teeth.

Main Sump Oil Level

Lubricating oil is supplied to the gears from the main engine lubricating system. The system has a connection to each bearing. Nozzles are located so that a constant spray of oil is directed over the gears. This constant spray of oil over the gears lubricates and cools the gears. In reduction gears, the maximum oil level in the sump may reach the bottom of the bull gear. An oil excluding pan is fitted around the bottom of the bull gear to ensure that the bull gear does not dip into the oil.

If the gear dips into the oil, the churning action of the gear will produce foam. Under normal conditions, only a small quantity of oil comes in contact with the bull gear; therefore, no dangerous vibration and no churning effect will

occur. Oil from the gears is swept out of the pan by the bull gear and drained into the sump. A drain hole on the bottom of the pan is located to drain any accumulated water when the ship is on an even keel. When there is too much oil in the sump, the gear will churn and aerate the oil. Because the aerated oil is a poor lubricant, there will be an increase in engine and oil temperature. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Make routine checks to see that the lubricating oil is maintained at the proper level. Any sudden loss or gain in the amount of oil in the main sump should be investigated immediately.

Effects of Acid and Water in Oil

Water and acid in oil are extremely dangerous. Test oil frequently for water and at regular periods for acid. Even a small amount of water in oil can cause pitting and rusting. Freshwater can accumulate because of leaking turbine packing glands or from condensation. Where main sump tanks are located at the skin of the ship, salt water may leak into the lube oil. Salt water may also enter through leaks in the lube-oil cooler. When salt water is found in a lube-oil system, take corrective steps to find and seal off the source of the salt water. Remove the contaminated oil from the system by flushing with clean oil.

When oil is contaminated with freshwater, adequate purification will prevent an accumulation of water in the oil. However, you must find and eliminate the source of water. Under normal operating conditions, operate the lube-oil purifier 12 hours a day while underway. However, if the presence of freshwater is noted, operate the purifier until there is no visual indication of water in the oil and no water is discharged from the purifier. If, with additional purifier operating time, the oil does not clear up, check the purifier for improper operation. Never ignore the presence of salt water or freshwater in lube oil. Check the system immediately and eliminate the source of contamination.

When the main engines are secured, keep a lube-oil pump running and keep the jacking gear engaged and turning until the engines have cooled to approximately room temperature (ambient). While oil is circulating, leave the lube-oil cooler in use and operate the purifier. Circulating oil will carry away the heat from the engines, which might otherwise reach the bearings. Turning the engines will prevent the rotors from becoming bowed. Operating the purifier will eliminate water caused by condensation on the interior of the reduction gear casing.

Ships should take every opportunity to have laboratory tests made of the lube oil. Good engineering practice dictates that this be done every 3 months, or more frequently in unusual conditions. Samples should be tested for water, acid, and sediment content. When the neutralization number exceeds 0.50, replace the lube oil.

Oil Emulsion

With continuous use, the lube oil will increase in acidity. The free fatty acids will form mineral soaps that can form a stable oil and water emulsion. Once the emulsion has formed, the removal of water becomes more difficult. More important, the oil loses its lubricating quality, the formation of an oil film becomes impossible, and the oil must be renovated. Emulsified oil will cause wiped bearings and worn gear teeth.

PREPARATION TO GET UNDERWAY

To prevent misunderstanding and confusion in preparing to get underway, use EOSS. It provides a convenient and simple procedure for checking the required steps in proper sequence. It ensures that no important step is overlooked or forgotten. Some of the most important steps are listed below:

1. Inspect the sump or supply to ensure there is enough oil for system operation.
2. Inspect for water in the lube oil at the bottom of the lube-oil sump.
3. Determine if circulating water is available at the lube-oil cooler.
4. The lube oil in the sump should be about 90 °F when you start the lube-oil pumps. It may be necessary to heat the oil before starting the lube-oil pump if it is below this temperature.
5. Make sure that oil is flowing freely at correct pressure to all gear shaft bearings, spray nozzles, and line shaft components. When the oil is flowing at operating temperature to all bearings and sprays, check the operating level in the sump or supply tank.

When the ship is underway, observe all oil pressures and temperatures to see that they remain normal. Record these pressures and temperatures hourly. Check the oil level in the sump frequently;

if the level changes, check for leaks. Take and post oil samples frequently. For more information on oil sampling, purification, and cleaning procedures, refer to *Naval Ships' Technical Manual,* chapter 9450.

NOISES AND VIBRATIONS

Once the ship is underway, you will need to be alert for any unusual noises and vibrations. On steam-turbine-driven ships, noises may occur at low speeds, when maneuvering, or when passing through shallow water. Generally, these noises do not result from any defect in the propulsion machinery and will not occur during normal operation. A rumbling sound that occurs at low-shaft rpm is generally caused by the low-pressure turbine gearing floating through its backlash. The rumbling and thumping noises that may occur during maneuvering or during operation in shallow water are caused by vibrations initiated by the propeller. These noises are characteristic only of some ships and should be regarded as normal sounds for these units. These sounds will disappear with a change of propeller rpm or when the other causes mentioned are no longer present. These noises can usually be noticed in destroyers when the ship is backing, especially in choppy seas or in ground swells.

Unusual Noises

A properly operating reduction gear has a definite sound. An experienced watch stander should be able to recognize these sounds at different speeds and under various operating conditions.

If any abnormal sounds occur, investigate immediately. Your investigation should depend on how you interpret the sound or noise.

The lube-oil temperature and pressure may or may not help you determine the reasons for the abnormal sounds. A badly wiped bearing may be indicated by a rapid rise in oil temperature for the individual bearing. A certain sound or noise may indicate misalignment or improper meshing of the gears. If unusual sounds are caused by misalignment of gears or foreign matter passing through the gear teeth, stop the shaft and make a thorough investigation before the gears are operated again.

For a wiped bearing or any other bearing casualty that has caused a very high temperature, follow this procedure: If the temperature of the lube oil leaving any bearing has exceeded the permissible limits, slow or stop the unit, and inspect the bearing for wear. The bearing may be wiped only a small amount, and the shaft may be operated at a reduced speed until the tactical situation allows sufficient time to inspect the bearing.

Vibration

The most common causes of vibration in a main reduction gear are faulty alignment, bent shafting, damaged propellers, and improper balance.

A gradual increase in the vibration in a main reduction gear that has been operating satisfactorily for a long period of time can usually be traced to a cause outside of the reduction gears. The turbine rotors, rather than the gears, are more likely to be out of balance.

When reduction gears are built, the gears are carefully balanced (both statically and dynamically). A small amount of unbalance in the gears will cause unusual noise, vibration, and abnormal wear of bearings.

When the ship has been damaged, vibration of the main reduction gear installation may be caused by misalignment of the turbine, the main shafting, the main shaft bearings, or the main reduction gear foundation. When vibration occurs within the main reduction gear, damage to the propeller should be one of the first things to be considered. The vulnerable position of the propellers makes them more liable to damage than other parts of the plant. Bent or broken propeller blades will transmit vibration to the main reduction gear. Propellers can also become fouled with line or cable, which will cause the gears to vibrate. No reduction gear vibration is too trivial to overlook. Always make a complete investigation.

LOCKING AND UNLOCKING THE MAIN SHAFT

There may be times when you need to stop and lock the main propeller shaft for an emergency or casualty. It may be necessary to stop the shaft in these conditions to prevent damage to the machinery while you resolve the problem. The best way to lock a propeller shaft while the ship is underway is to wait for the shaft to stop, engage the turning gear, and then apply the brake.

CAUTION

During drills the shaft should not be locked more than 5 minutes, if possible. The ahead throttle should NEVER be opened when the turning gear is engaged. The torque produced by the ahead engines is in the same direction as the torque of the locked shaft; to open the ahead throttle would result in damage to the turning gear.

Locking the Main Shaft

Engine-room personnel should be trained through drills to safely lock and unlock the main shaft. Each steaming watch should have enough trained personnel available for this purpose.

The maximum safe operating speed of a ship with a locked shaft can be found in the manufacturer's technical manual. Additional information on the safe maximum speed that your ship can steam with a locked shaft can be found in *Naval Ships' Technical Manual,* chapter 9420.

Unlocking the Main Shaft

If practical, the simplest way to unlock the shaft is to stop the ship, release the turning gear and brake, and warm the turbines. If the shaft has been locked for 5 minutes or more, the turbine rotors may have become bowed, and special precautions are recommended.

Before the shaft is turned, station personnel at the turbines to check for unusual noises and vibration. If, when the propeller starts to turn, vibration indicates a bowed rotor, the ship's speed should be reduced to the point that you notice little or no turbine vibration. Maintain this speed until the rotor is straightened. When the shaft is operated at that speed, the steam passing through the ahead throttle will warm the rotor and help straighten it. You can lower the main condenser vacuum to add additional heat to the turbines; this will increase the exhaust pressure and temperature.

As the vibration decreases, increase the shaft speed slowly and continue to check for vibration. The turbine is not ready for normal operation until vibration has disappeared at all possible speeds.

MAINTENANCE OF A MAIN REDUCTION GEAR

Under normal conditions, a shipyard should handle major repairs and major items of maintenance on a main reduction gear. When a ship is deployed overseas and at other times when shipyard facilities are not available, emergency repairs should be done, if possible, by a repair ship or an advanced base. Inspections, checks, and minor repairs should be done by the ship's force.

BEARING MAINTENANCE

Under normal conditions, the main reduction gear bearings and gears will operate for an indefinite period. Enough spares are carried aboard to replace 50 percent of the number of bearings in the main reduction gear. Usually each bearing is interchangeable for the starboard or port installation. Check the manufacturer's technical manual to determine interchangeability of gear bearings.

Special tools and equipment needed to lift main reduction gear covers, to handle the quill shaft when removing bearings from it, and to take required readings and measurements are normally carried aboard. These items are carried in case emergency repairs have to be made by repair ships or bases not required to carry these items.

The manufacturer's technical manual is the best source of information concerning repairs and maintenance of any specific reduction gear installation.

Journal Bearings

Each babbitted bearing shell of the reduction gear may be considered as having a pressure bearing half and a nonpressure bearing half. The nonpressure bearing half has a radial scribe line at one end of the geometric center. The pressure bearing half has three radial scribe lines at one end. The central scribe is at the geometric center, and the additional scribes on either side of the central scribe are at an angle of 45°. These scribes are placed by the manufacturer. The crown thickness of each shell, at these scribe points, is measured with a micrometer, usually 1 1/4 inches from the end of the shell. Such measurements are taken during the initial alignment by the manufacturer. They are stenciled adjacent to each scribe line to be used as constants for future alignment checks. In this way the amount of wear can always

Some older ships are not equipped to check alignment by the crown-thickness and proof-staff methods. On these ships, the gears are first checked for alignment by measuring the percentage of tooth contact in accordance with *Naval Ships' Technical Manual,* chapter 9420.

After alignment is established, remove and mark the bearings. Measure the crown thickness of the bearing and stencil the measurement adjacent to each scribe line. Measure subsequent bearing wear by using the crown-thickness method based on the constants as stenciled.

The amount of bearing clearance allowed should not be great enough to allow incorrect gear tooth contact. The designed bearing clearances are given in the manufacturer's technical manual. These clearances are also given in the blueprints for the main reduction gear. The maximum allowable clearance can be found in *Naval Ships' Technical Manual,* chapter 9420.

Replacing bearings in the main reduction gear is a major undertaking. When a casualty (such as the loss of lube oil) occurs, the high-speed pinion shaft bearings are more likely to be wiped than the other main gear bearings. These high-speed pinion shafts are coupled to the high-pressure and low-pressure turbines. They will have a higher rotary speed than other shafts in the reduction gear. If the bearings are inspected, the high-speed pinion bearings should be checked first. If these bearings are not wiped, it is safe to assume that the bearings that rotate at lower speeds are not wiped. If you make repairs, first study the manufacturer's technical manual and the blueprints for the main reduction gear. As an MM1 or MMC, you should be able to decide whether the repair work should be attempted. You should also have a clear understanding of the construction details and repair procedures before starting a repair job. Other factors to be considered are location of the ship, available repair facilities, available repair parts, and the operating schedule of the ship.

In making repairs, the first step is to engage the turning gear and set the brake to ensure that the shaft will not turn while repairs are being made. Pump all oil out of the main sump tank. Store the oil in a clean settling or storage tank until it is ready for use again. Next, lift a section of the reduction gear cover by using chain falls and wire slings. When the gear cover is moved out of the way, remove the bearing cover. Next, turn the bearing so that the bearing split is on the when the bottom half of the bearing is removed. Roll a dummy bearing in while the lower half is rolled out. The dummy bearing supports the weight of the shaft and keeps the shaft in position. Take special precautions to prevent the shaft from being turned or lifted, which may allow the gear teeth to become unmeshed. If the gear teeth become unmeshed and are not matchmarked, a complicated and detailed procedure must be followed to reassemble and time the gears. The setting up of the locked-train gear system is done at the factory and at shipyards.

If the bearing has excessive clearance, is badly wiped, or is heavily scored, examine other representative bearings to determine the extent of the damage. Replace all bearings on that particular shaft to maintain correct gear alignment.

To replace a bearing, proceed as follows:

1. Review the maintenance history of the reduction gears to determine if special bearings are necessary.
2. Measure the diameter of the journal (with a micrometer) and compare the present readings with the original readings, as recorded.
3. Check the crown thicknesses of installed and replacement bearings and compare readings. If scraping is required for the replacement bearing, use a full-sized mandrel and prussian blue to check the work. Shaft parallelism must be maintained.
4. To maintain shaft parallelism, ensure that bearings on the ends of gear or pinion shafts do not differ more than 0.002 inch.
5. When a spare bearing is installed or a damaged bearing is scraped to maintain correct tooth contact, stamp the crown thickness on the bearing shell.
6. Use dowels between the bearing halves to locate the bearings in the upper casing. Upper and lower bearing halves must be mated parts. Interchanging of upper and lower bearing halves is prohibited.
7. Examine the condition of the journal whenever bearings are removed. If the surface of the journal is slightly scored, it must be stoned very lightly and polished. Only experienced personnel should stone a journal. Always oil a journal before rolling in a new bearing.

NOTE: If journals are badly scored, they may be ground undersize or restored to design diameter by chrome plating. If a journal is ground

undersize, it might be necessary to provide undersize bearings. This should be done only by a shipyard and in accordance with existing NAVSEA instructions. The new journal diameters and bearing clearances must be recorded.

When installing a spare bearing, make sure it is well oiled; then roll the lower half into position, removing the dummy bearing. Place the upper half in position, and then shift the complete bearing to its proper position. Ensure that the dowels are in place and that the bearing assembly is in its required position, in accordance with the manufacturer's instructions. Lower the bearing cap into position and securely bolt it down.

Before the gear cover is lowered into position, make a careful inspection to see that the inside of the gear installation is free of all dirt, tools, rags, and other foreign matter that would be harmful to the gears. After the gear cover is lowered into position and bolted down, pump the lube oil to the sump. Before the oil is circulated through the system, place muslin bags in oil strainers. The muslin bags will trap any dirt or foreign matter that is too fine to be stopped by the strainer. Start a lube-oil service pump to circulate oil through the system. Change the muslin bags at 30-minute intervals until they no longer pick up dirt. Then you can engage and start the turning gear.

Thrust Bearings

This chapter contains only general information on different methods of taking end-play readings on the main thrust bearing. See the manufacturer's technical manual for specific information on any given unit.

Always check the end play for any six- or eight-shoe thrust bearing with the top half of the bearing bolted down solidly; otherwise, the base rings will tilt because of the freedom of movement given the leveling plates, and you will get a false reading.

Keep and refer to a record of the main thrust readings when you check the main thrust bearing. Over a period of years, the normal wear of a pivoted-shoe thrust bearing is negligible. However, when the bearing is new, the leveling plate may settle slightly. If any increase occurs in the end play of a main thrust bearing, inspect the surfaces of the thrust shoes and make necessary repairs.

Some main thrust bearings have a port (in the main thrust bearing cap over the thrust shoes) for inspection purposes. This port has a removable cover of sufficient size to permit the withdrawal of thrust shoes that are in line with it.

CHECKING THRUST WHILE UNDERWAY.—The simplest means of checking end play is to use a dial indicator on any accessible flange on the main shaft while the engines are going slowly ahead and then astern. This can usually be done when the ship is maneuvering to approach a pier or an anchorage. The speeds should be slow enough to avoid adding deflections of bearings parts and housing to the actual end play. But, the speed should be sufficient enough to ensure that the full end play is actually taken up.

Some ships have the main thrust bearing located at the forward end of the main reduction gear and constructed as a component part of the gear. Use a spring-loaded pin gage (located in the bearing end cover housing) and a micrometer depth gage to measure the end play. Remove the pin gage cover and place the anvil of the depth gage on the machined surface of the pin gage housing. Carefully turn the micrometer so that the spindle pushes the installed pin against the main shaft. Take up all slack; but do not use excessive force, as it will lift the micrometer anvil from the machined surface.

Take another reading with the main shaft operating in the opposite direction. The difference between the two readings is the end play. It is always good practice to take more than one set of readings to ensure that the total end play was taken up and that the readings are accurate.

JACKING ON A SHAFT FLANGE.—If it is not practical to measure the end play while the engine is running, the next choice is to jack the shaft (while it is still warm) fore and aft at some convenient main shaft flange. Mount a dial indicator on a rigid support, convenient to some main shaft flange, and jack the shaft forward and then astern. Make certain that the shaft movement is free—but do not use too great a force; excessive force might cause deflections of metal parts to be added to the actual end play. The main difficulty in using the jacking method is finding suitable supports where no structural damage will be done.

GEAR TEETH

The importance of proper gear tooth contact cannot be overemphasized. Any abnormal condition that may be revealed by operational sounds or by inspections should be corrected as soon as possible. Any abnormal condition that is not

corrected will cause excessive wear, which may result in general disintegration of the tooth surfaces.

If proper tooth contact is obtained when the gears are installed, little wear of teeth will occur. Excessive wear cannot take place without metallic contact. Proper clearances and adequate lubrication will prevent most gear tooth trouble.

Wear-in of Gear Teeth

Gears that have been realigned and new gears should be given a wearing-in period at low power before they are subjected to the maximum tooth pressure at full power.

Tooth Contact

For proper operation of the gears, the total tooth pressure must be uniformly distributed over the total area of the tooth faces. This uniform pressure is accomplished by accurate alignment and adherence to the designed clearance.

Maintain the designed center-to-center distance of the axes of the rotating elements as accurately as practical. However, the axes of pinions and gear shafts must always be parallel. If the shafts are not parallel, the load is concentrated on one end of a helix. The result may be flaking, galling, pitting, featheredges on teeth, deformation of tooth contour, or breakage of tooth ends.

Checking Tooth Contact

The length of tooth contact across the face of the pinion is a means of determining if reduction gear alignment is satisfactory. One method used to static check the length of tooth contact is to apply a thin coat of prussian blue to a band of teeth on one element and to coat a similar band on the mating element with red lead. The coatings must be thin and even. Rotate the two bands into contact by jacking back and forth three or four times.

Use either copper sulfate or blue or red Dykem to determine tooth contact for operating conditions. Use Dykem for dock trials, because it will show markings for light load conditions. Copper sulfate markings will remain visible longer after high-power operations than will Dykem markings. Remove lubricating oil from the gear teeth with a cleaning agent before you apply the compound. After the tooth contact is determined, remove the compound from the gear teeth to prevent possible contamination of the lubricating oil. Then oil the gear teeth.

Remember that some gear teeth are cut with a very slight taper to offset the effects of torsional twist and bending. In such gearing, full contact across the teeth will not be obtained.

Tooth Contour

The designed tooth contour must be maintained. A lack of this tooth contour can cause load concentrations with consequent scoring.

Tooth Surface Wear

If proper contact is obtained when the gears are installed, the initial wearing, which takes place under conditions of normal load and adequate lubrication, will smooth out rough and uneven places on the gear teeth. This initial wearing is referred to as *normal wear* or *running in*. As long as operating conditions remain normal, no further wear will occur.

Small shallow pits, starting near the pitch line, will frequently form during the initial stage of operation; this process is called *initial pitting*. Often the pits (about the size of a pinhead or even smaller) can be seen only under a magnifying glass. These pits are not detrimental and usually disappear in the course of normal wear.

Pitting that is progressive and continues at an increasing rate is known as *destructive pitting*. The pits are fairly large and are relatively deep. Destructive pitting is not likely to occur under proper operating conditions. It can be caused by excessive loading, too soft material, or improper lubrication. This type of pitting is usually caused by misalignment or improper lubrication.

The condition in which groups of scratches appear on the teeth (from the bottom to the top of the tooth) is termed abrasion, or scratching. It may be caused by inadequate lubrication or by foreign matter in the lubricating oil. When abrasion, or scratching, is noted, you should immediately examine the lubricating system and the gear spray fixtures. If you find that dirty oil is responsible, the system must be thoroughly cleaned and the whole charge of oil centrifuged.

The term *scoring* denotes a general roughening of the whole tooth surface. Scoring marks are deeper and more pronounced than scratching; they cover an area of the tooth instead of occurring haphazardly, as in scratching, or abrasion. Small areas of scoring may occur in the same position on all teeth. Scoring, with proper

alignment and operation, usually results from inadequate lubrication and is intensified by the use of dirty oil. If these conditions are not corrected, continued operation will result in a general disintegration of the tooth surfaces.

Spotting Gear Teeth

If you find any abnormal conditions that may be revealed by operational sounds or by inspections, correct them with the least possible delay. Stone rough gear teeth until they are smooth if you are certain that the roughening was caused by the passage of some foreign matter. Investigate any tooth deterioration that cannot be traced to a casualty. Give special attention to the condition of the bearing, to lubrication, and to the possibility of a change in the supporting structure, which has disturbed the parallelism of the rotors.

To spot-in surfaces of reduction gear teeth, coat the pinion teeth lightly with prussian blue. Then turn the gear in its ahead direction by using the jacking gear. As the gear teeth come in contact with the marked pinion teeth, an impression is left on the high part of the gear tooth. After the gear is turned one-fourth turn or is in a convenient position for stoning, use a small handstone to remove all high spots indicated by the marks. You will need to replace the bluing on the pinion teeth repeatedly; but if the bluing is applied too thickly, false impressions will be left on the teeth.

You may scrape gear teeth to remove a local hump or deformation; however, you may not scrape gear teeth to obtain contact without the approval of the Naval Sea Systems Command.

Backlash

Backlash is the play between the unloaded surfaces of the teeth in mesh on the pitch circle. Backlash increases with wear and can increase considerably without causing trouble.

Root Clearance

The designed root clearance with gear and pinion operating on their designed centers can be obtained from the manufacturer's blueprints. The actual clearance can be found by taking leads or by inserting a long feeler gage or wedge. The actual clearance should check with the designed clearance. If the root clearance is considerably different at the two ends, the pinion and gear shaft will not be parallel. There should be sufficient backlash, and the teeth should not mesh so closely that lubrication is poor or that clearance is reduced below specified limits. If these conditions are present, the tolerance will be satisfactory.

SHAFT ALIGNMENT

Under normal conditions all alignment inspections and checks, plus the necessary repairs, are done by naval shipyards. Incorrect alignment will be indicated by abnormal vibration, unusual noise, and wear of the flexible couplings or main reduction gears. When misalignment is indicated, a detailed inspection should be made by shipyard personnel.

Main Propeller Shafting

Two sets of readings are required to get an accurate check of the propulsion shafting. One set of readings is taken with the ship in drydock; and another set is taken with the ship waterborne—under normal loading conditions. The main shaft is disconnected, marked, and turned so that a set of readings can be taken in four different positions. These readings are taken on the top, bottom, and on both sides. The alignment of the shaft can be determined by studying the different readings. The naval shipyard will decide whether or not corrections in alignment are necessary.

Turbine Shafting

The high-pressure turbine shaft and the low-pressure turbine shaft are connected to their respective first-reduction pinions by flexible couplings. Each of the first-reduction couplings consists of two sleeves with internal teeth that mate with external teeth on a distance piece or extension shaft. One sleeve is bolted to the turbine flange, and the other is bolted to the first-reduction pinion flange. Lubricating oil is fed to the meshing-sleeve and distance-piece teeth from nozzles supplied with oil from the adjacent bearing. The couplings are fitted with rings that dam the oil flow through the teeth. This causes the oil level to be as deep as the tooth height and ensures lubrication to all contacting surfaces.

Flexible couplings permit axial motion and expansion of turbine rotors but will compensate for only a very small amount of misalignment. Therefore, correct alignment of turbine shafts and first-reduction pinion shafts is extremely important. When a new unit is installed properly, there is little difficulty with misalignment.

However, abnormal clearance in a turbine bearing or pinion bearing will cause misalignment of the flexible coupling.

INSPECTIONS

The minimum tests and inspections should be conducted in accordance with the shipboard preventive maintenance program. An example of the requirements are shown on the maintenance index page (fig. 3-3). When defects are suspected or operating conditions indicate the necessity, you should make inspections at more frequent intervals.

> **CAUTION**
>
> Any disassembly and assembly of a large reduction gear should be done in a shipyard under the guidance of trained personnel or manufacturers' representatives. When the ship is not in a shipyard, permission to open any portion of the gear casing or the access openings, plugs, piping, or attached fixtures must come from the ship's officers.

Before replacing any cover, connection, or inspection plate that permits access to the gear casing, an officer of the engineering department should make a careful inspection to ensure that no foreign matter has entered, or remains in, the casing. If the work is being done by a repair activity, an officer from that activity must also inspect the gear casing. The inspections and the name of the officer or officers must be entered in the engineering log.

Shipyard Overhaul

During shipyard overhauls, the following inspections should be made:

- Inspect condition and clearance of thrust shoes to ensure proper position of gears. Blow out thrusts with dry air after the inspection. Record the readings. Inspect the thrust collar, nut, and locking device.

- If turbine coupling inspection has indicated undue wear, check alignment between pinions and turbines.

- Pump the oil out of the gear sump and clean the sump internally. Scrape off and remove rust deposits from the sump.

- Inspect turning gear assemblies for proper operation and condition.

Ten-year Inspection

When conditions warrant or if trouble is suspected, submit a work request to a naval shipyard to perform a 10-year inspection of the main reduction gear. Shipyard personnel should perform the following inspections and related actions:

- Inspect to determine the condition of all bearings, journals, and gear teeth. Record the bearing crown thickness or lead readings of all main pinion and gear bearings.

- Check the intermediate coupling bolts for tightness.

- Take and record alignment readings of the prime mover to the gear. Do this with the ship waterborne and the propulsion plant in the ready-to-operate condition.

Naval Sea Systems Command authorization is not necessary to lift reduction gear covers. These covers should be lifted when you suspect trouble. However, an open gear case is a serious hazard to the main plant. Through this opening, rags can get in oil lines, and tools can get in gear teeth. These kinds of mistakes have caused serious and expensive casualties that were attributable directly to a lifted gear cover. Before you lift a gear cover, carefully consider the dangers of uncovering the gear against the reasons for suspecting internal trouble. The 10-year inspection may be extended by the type commander when operating conditions indicate that a longer interval between inspections is desirable.

Before Trials

Before a trial, you should make the following inspections, in addition to those which may be directed by proper authority: Open the inspection plates; examine the tooth contact, the condition of teeth, and the operation of the spray nozzles. You should not open gear cases, bearings, and thrusts immediately before trials.

System, Subsystem, or Component	Reference Publications
Reduction Gears	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
MB	ZZZFGE5	35	5025	Q	1. Inspect the reduction gear including spray nozzles.	Q-1	EO MM1 MM3	 1.0 1.0	None
MB	ZZ2FSC1	65	4290	Q	1. Measure main shaft thrust clearance.	Q-2	EO MM1 MM2	 0.3 0.3	None
MB	ZZZFGE1	84	5064	S	1. Inspect and clean oil sump and reduction gear casing.	S-1	EO MM1 MM3 2FN	 5.0 6.0 12.0	None
MB	ZZ1FCW4	65	A188	A	1. Inspect flexible couplings. Measure clearances.	A-1	MMC MM1 2FN	2.0 8.0 16.0	None
MB	ZZZFGE5	78	6669	A	1. Sound and tighten foundation bolts.	A-2	FN	1.0	None

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Figure 3-3.—Maintenance index page.

After a trial, you should make the following inspections, in addition to those which may be directed by proper authority: Open the inspection plates and examine the tooth contact and the condition of the teeth to note changes that may have occurred during the trials. Running the engines for a few hours at high power will show any possible condition of improper contact or abnormal wear that would not have shown up in months of operation at lower power. Check the clearance of the main thrust bearing.

REDUCTION GEAR SECURITY

All inspection covers, whether hinged, pinned, or bolted, should be secured by locks of a high-security type. The custody of keys for these locks is the responsibility of the engineering officer. Plates and panels secured with more than 12 bolts or nuts need not be locked. Piping and fixtures need not be locked but should be secured to prevent unauthorized access to gear internals. You should carry out an ongoing program of security training of engineering personnel. Encourage all hands to recognize and report instances that may lead to unauthorized entry into the main reduction gear. For detailed information on ways to improve reduction gear security, refer to *Naval Ships' Technical Manual,* chapter 9420.

SAFETY PRECAUTIONS

Anyone who works around a main reduction gear should understand and use the following safety precautions:

- If churning or emulsification of oil and water occurs in the gear case, slow down or stop the gear until the defect is remedied.

- If the supply of oil to the gear fails, stop the gear until the cause can be located and remedied.

- When bearings have been overheated, do not operate the gear, except in extreme emergencies, until bearings have been examined and defects remedied.

- If excessive flaking of metal from the gear teeth occurs, do not adjust the gears, except in an emergency, until the cause has been corrected.

operate the gear cautiously until the cause for the noise has been discovered and corrected.

- Do not remove any inspection plate, connection, fitting, or cover that permits access to the gear casing without specific authorization by the engineering officer.

- Keep the immediate vicinity of an inspection plate free from paint and dirt.

- When gear cases are open, take precautions to prevent the entry of foreign matter. Never leave the openings unattended unless satisfactory temporary closures have been installed.

- Inspect lifting devices carefully before using them, and do not overload them.

- When ships are anchored in localities where there are strong currents or tides, lock the main shaft.

- When the rotation of the propellers may cause injury to a diver over the side or damage to the equipment, lock the propeller shafts.

- When a ship is being towed, lock the propellers unless it is permissible and advantageous to allow the shafts to trail with the movement of the ship.

- When a shaft is allowed to turn or trail, the lubrication system must be in operation. In addition, keep a careful watch on the temperature within the low-pressure turbine casing to see that windage temperatures cannot be built up to a dangerous degree. This can be controlled either by the speed of the ship or by maintaining vacuum in the main condenser.

- Bring the main propeller shaft to a complete stop before engaging the clutch of the turning gear. (If the shaft is turning, it will cause considerable damage to the turning gear.)

- When the turning gear is engaged, set the brake quickly and securely to prevent the shaft from turning and damaging the turning gear.

- When a main shaft is to be unlocked, take precautions to disengage the turning gear clutch before releasing the brake. If the brake is released first, the main shaft may begin to rotate and cause injury to the turning gear and to personnel.

- In an emergency, when the ship is steaming at a high speed, you can stop the main shaft and hold it stationary by the astern turbine until the ship has slowed down to a speed at which you can safely lock the main shaft.

- When there is a limiting maximum safe speed at which a ship can steam with a locked propeller shaft, know this speed and do not exceed it.

- Before the turning gear is engaged and started, check to see that the turning gear is properly lubricated. Some ships have a valve in the oil supply line leading to the turning gear. See that a lube-oil service pump is in operation and that the proper oil pressure is being supplied to the turning gear before the motor is started.

- Definitely determine that the turning gear has been disengaged before the main engines are turned over.

- While working on or inspecting an open main reduction gear, the person or persons performing the work should not have any article about their person that may accidentally fall into the gear case.

- Tools, lights, and mirrors used to work on or inspect gears, bearings, and so forth, should be lashed and secured to prevent them from being accidentally dropped into the gear case.

SUMMARY

This chapter has given you an overview of main reduction gears. It is not intended as a substitute for information on operations and maintenance manuals; we have referred to those publications where it was appropriate.

You were introduced to the types of reduction gears and their operations. You were given information on lubrication, getting underway, checking for unusual noises, and some of the procedures used to maintain the gears and their related parts. Last, you were given some pointers on reduction gear security and safety precautions.

If some of these areas are not as clear as they should be to you, review them now while you remember the gaps in your knowledge.

If you have questions about this chapter, write to NAVAL EDUCATION AND TRAINING PROGRAM MANAGEMENT SUPPORT ACTIVITY, CODE 312, SAUFLEY FIELD, PENSACOLA, FL 32509-5000.

CHAPTER 4

STEAM-DRIVEN GENERATORS

Electrical power, a vital part of today's modern Navy, is provided throughout naval ships by steam-driven turbogenerators. The number and size of the generators aboard each class of ship are determined by such factors as safety, reliability, and power requirements. Now, in the computer age, the demand for turbogenerator reliability is greater than ever.

OPERATING GENERATOR TURBINES

In this chapter, we will discuss the factors that contribute to generator reliability, operation, inspection, maintenance, and repair. Before studying the material in this chapter, you may find it helpful to review chapter 2, "Steam Turbines," in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-F.

STARTING GENERATOR TURBINES

When a turbine is first put into service, it is subject to variable expansion caused by changing conditions in internal pressure and temperature. Therefore, you need to allow a reasonable length of time for the turbine to warm up, to gradually come up to speed, and to apply its load. If the instructions of the turbine manufacturer and the engineering operational sequencing system (EOSS) are carefully observed, you will have a successful operation.

When starting a turbine that is driving an electric generator, follow these procedures:

1. Ensure that the turbine is free of all loose material and that all working parts are clean and well lubricated. Test all safety devices where practical, tripping them by hand to ensure proper functioning.
2. Be sure that the temperature of oil in the sump is at least 60 °F. The level of oil in the sump should be approximately at the maximum mark on the oil level gauge.
3. Take and record the cold reading of the axial setting of the rotor. This can be done with a rotor position indicator or micrometer.
4. Turn the unit by hand if a strap wrench is provided. It should turn easily and without noise or grinding of any kind.
5. Ensure the overspeed trip mechanism is properly set.
6. Open the drain valves ahead of the throttle valve; warm the piping gradually and drain all condensate.
7. Place the auxiliary condenser into service and bring up the vacuum to about 15 inches of mercury.
8. Start the oil pump, and pump oil to the bearings. Some older generators may have a hand oil pump. In that case, turn the hand oil pump continuously until the attached pump takes charge. Check pressure gauges and sight flows to be sure that all bearings are receiving oil. The controlling valves generally are lifted by oil pressure from the pump, after which the throttle valve can be opened sufficiently to start the rotor spinning. Once the rotor has started revolving, immediately trip the throttle valve by hand to see that the tripping mechanism operates properly. Then reset the overspeed trip and again open the throttle valve to keep the rotor turning slowly.
9. Admit gland sealing steam to the shaft packings.
10. Bring the rotor to half speed and run at that speed for several minutes to warm up the casing and rotor. During the warming period, watch all bearing oil temperatures and listen for any rubbing, vibration, or other unusual noise.
11. When the temperature of the oil leaving the bearings reaches about 100 °F, start circulating water in the oil cooler. Regulate the flow to maintain the temperature of the oil.
12. When the turbine is satisfactorily warmed up, close the drain valves, increase vacuum, and bring the turbine up to operating speed.

When the unit is operating properly under control of the governor, the generator may be placed on the line in accordance with EOP. During normal operations of the turbine-driven generator, make periodic checks of sight flows, strainer baskets, pressures, and bearing temperatures. Record them on the appropriate logs. The satisfactory operation of the generator depends largely on the care it receives. Watch standing, as well as tests and inspections, should be performed in accordance with the requirements of the applicable technical manuals, the EOSS, and the engineering operation casualty control (EOCC).

SECURING GENERATOR TURBINES

One essential step to long life and successful operation of a turbine-driven generator is to ensure that it is properly secured. Improper securing may lead to corrosion of internal parts. The following are general procedures used to secure a generator turbine:

1. Remove the electrical load from the generator.
2. Close the throttle valve by striking the hand trip or overspeed tripping mechanism.
3. If the generator is equipped with a hand pump, operate that pump until the rotor stops to avoid unnecessary bearing wear.
4. Secure the steam supply to the packing.
5. Shut off the water to the oil cooler.
6. Close the root steam valve and open the drain valves to relieve pressure and drain the lines.
7. After all the condensate has drained out and the casing has cooled to engine-room temperature, close all the drains. To prevent corrosion, take every precaution to guard against steam bleeding into the turbine casing.

If you use the above procedures and correctly follow the EOSS, the turbine-driven generators will require less maintenance and repairs. This will increase the reliability of each unit.

TURBOGENERATOR MAINTENANCE

Satisfactory operation of turbogenerators depends largely on the care they receive. Perform all tests, inspections, preventive maintenance, and repairs in accordance with the planned maintenance system (PMS) and applicable technical equipment manuals.

One operating trouble that may result from improper maintenance is vibration. Before going into the actual details of maintenance, therefore, we will take a look at some of the causes of vibration.

VIBRATION

Vibration in a turbine indicates that the unit is not in proper working condition. As soon as this condition is noted, make a thorough investigation to determine the cause of the trouble. If you do not deal with the trouble immediately, defects will accumulate. Bearing and packing clearances will become excessive, and the bearings and packing will soon be ruined. If the turbine is kept in operation, further trouble may develop, which may result in complete disablement of the unit.

All rotating parts are balanced statically and dynamically before the unit is installed. Improper balance is not usually caused by excessive vibration. Instead, excessive vibration can almost always be traced to one or more of the following defects caused by improper maintenance:

- Wiped bearings or excessive oil clearance
- Worn thrust bearings
- Parts rubbing or binding (gland seal rings)
- Loose or broken foundation bolts
- Carbon or labyrinth packing clearances too small
- Misalignment between turbine and generator
- A bent shaft
- Damaged blading

Should a turbine vibrate to such an extent that you suspect an out-of-balance condition, take the following steps:

1. Examine all journal bearings and renew any bearings that have excessive clearances.
2. Examine the thrust bearing. Renew the thrust bearing if the clearance is excessive.
3. Inspect the turbine rotor for signs of damage, if inspection ports are provided.

4. Check the shaft packing rings for heating colors. If the clearance is too small, the vibration will become worse and the shaft will overheat. Stop and renew packing rings.

5. Check the shaft coupling bolts.

6. Check the coupling alignment.

7. Look for loose bolts in the unit. Replace or tighten bolts as necessary.

8. After completing steps 1 through 7, reassemble the unit and operate it at normal speed to see if the excessive vibration has been eliminated.

If the turbine continues to vibrate excessively, it is probably out of balance. In this event, a balance test must be made. Portable vibrational test equipment, available on tenders and repair ships, may be used to make a balance test with the turbine in place; or the unit may be tested at a shipyard. Only experienced personnel should be permitted to balance a turbogenerator, and the instructions of the manufacturer must be followed carefully. Details of the balancing must be recorded.

TURBINE MAINTENANCE

Steam turbine construction is relatively simple, and its basic reliability comes from this fact. The turbine contains few moving parts and practically no wearing types of parts. If the various linkages are kept greased, lubricating oil and steam are kept clean, and proper warming and securing procedures are followed, the turbine should operate for many years without any parts replacement. Primary shipboard maintenance objectives include a continuing awareness of changes in performance. Therefore, it is necessary to keep systems clean and to periodically check internal clearances.

Generator turbine maintenance requires regular inspections or checks of the maintenance items. Maintenance requirement cards (MRCs) for turbines are required for each preventive maintenance task. Where the PMS coverage applies, preventive maintenance should be conducted in accordance with the MRCs.

Gland Packing Maintenance

Packing is fitted around the shafts of generator turbines. This packing prevents leakage of steam from an ingress of air into the turbines under all conditions of operation. The staff packing must function properly to ensure efficient operation of a turbine. The shaft packing used on most turbogenerators is labyrinth-type rings or seals. This design simplifies the removal, repair, or replacement of packing.

Replace packing rings that show excessive wear. When new packing cannot be procured nor manufactured in the time frame available for turbine repairs, the existing rings can usually be machined to restore design clearances. In some cases you may have to replace the amount of metal removed by building up the outside diameter of the ring.

To obtain maximum effective sealing, maintain the tip width of packing teeth at 0.010 inch. Resharpen blunted teeth by scraping their sides. You can use either a bearing scraper or a cutting tool slotted to the shape of the tooth. Take care to avoid reduction of tooth height. For more information concerning repair of labyrinth packing, see *Naval Ships' Technical Manual,* chapter 231.

Turbine Casing Joints

Take extreme care in cleaning turbine casing joints. Carefully scrape and clean joint surfaces, then polish them with crocus cloth. Carefully inspect the joint faces for burrs and bruises. Never use sheet gasket material to remake a steam casing joint.

To seal the joint of a turbine, coat the surfaces with a thin layer of linseed oil and graphite or copalite. Set up opposite bolts fairly tightly and then follow around until all bolts are firmly secured.

The horizontal joint of some generator turbines is grooved in the lower half to provide a means for pressure pumping the groove with a sealing compound. Do not fill these grooves except in an emergency. Do not fill them during routine overhaul unless the flange surfaces are in poor condition and time and facilities do not permit resurfacing. Use only approved compounds to fill these grooves.

To fill the grooves, remove one end plug and the adjacent plug. Using the gun provided, start at the end hole and pump in the sealing compound until it flows out of the adjacent hole. Now, plug the first hole and place the gun in the adjacent hole. Remove the plug from the next hole and fill the next section of the groove in the same manner. Continue until the entire groove is filled. With the gun in the next to the last hole and with the sealing compound flowing from the last hole, plug the end hole and put pressure

on the entire groove. Then remove the gun, and plug the next to the last hole.

Once this operation has been started, carry it out rapidly and continuously to finish filling the groove before the sealing compound hardens.

Rotor Clearances

Axial flow turbines are usually provided with an opening in the casing to check blade clearance. As with main propulsion turbines, insert a tapered gauge between the nozzle diaphragm and the adjacent row of blades to measure blade clearance. If the blade clearance is outside the limits prescribed by the manufacturer, adjust the position of the rotor by changing the thickness of the filler piece in the thrust bearing before the unit is operated again. After each rotor adjustment, rotate the unit by hand to make sure there is no rubbing, binding, or undue friction. Also, check the gear tooth contact of the reduction gear.

Nozzle Diaphragm Maintenance

Repairs of labyrinth packing in nozzle diaphragms are normally done by shipyard, tender, or repair ship personnel. However, you should be familiar with the procedures. See the manufacturer's technical manual for more detailed information.

Nozzle diaphragms (fig. 4-1) are part of each stage of a pressure-compounded impulse turbine. Labyrinth packing and, in a few cases, carbon seals are used between the inner bore of the nozzle diaphragm and the rotor to seal against steam leakage.

To inspect or renew the labyrinth packing in a nozzle diaphragm, you must remove the upper half of the turbine casing. When the casing is lifted, the upper half of the diaphragms and the labyrinth packing will remain in the upper half of the turbine casing. When the casing has been moved to a convenient location, the segments of labyrinth packing can be removed by pushing them around in their grooves, away from the stop pin.

Corrosion

Inspect the turbine casing, especially near glands and in locations where water may collect in pockets or in lagging. Experience has shown that where water or dampness remains in contact with the casing, corrosion can seriously weaken the casing. Be sure that drain holes provided in pockets are kept open and of sufficient size. When corrosion is evident, remove the lagging and scrape down the surface of the casing to good metal. Next, dry and paint the surface with two coats of approved paint. Then replace the lagging and take steps to prevent recurrence of corrosion.

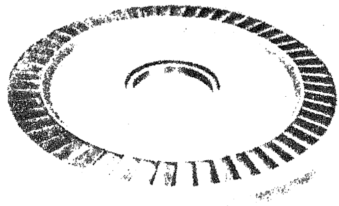

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Figure 4-1.—Nozzle diaphragm with labyrinth packing.

You can prevent most internal corrosion and rusting that impairs reliability and economy of turbine operation. Do this by continuing operation of air ejectors for a short time to dry the machine after it has been shut down and while it is still hot. The blade path of the turbine is provided with passages to drain any condensate in interblade row cavities.

In some cases, serious corrosion has been caused by chemical action. Inspect interiors as frequently as possible. If corrosion has begun, determine its cause and eliminate it. You can use a mirror to help inspect the interior of a turbine. Be careful that you do not drop it inside the turbine. Refer to PMS or *Naval Ships' Technical Manual,* chapter 231, for required inspection intervals.

REDUCTION GEAR MAINTENANCE

Turbogenerator reduction gears are generally of the single-reduction, single-helical type, with a reduction of about 8 to 1. In three-bearing designs, the pinion is forged and cut integral with its shaft. One end of the pinion shaft has a flange that bolts rigidly to the turbine shaft, and one end of the turbine rotor is supported by the pinion bearing. The other end of the pinion shaft has an extension on which the high-speed thrust bearing is assembled. In four-bearing designs, the pinion shaft is flexibly coupled to the turbine shaft, with two bearings supporting each shaft.

A flexible coupling of the double-ended dental type is usually used in these four-bearing designs.

The gear wheel is forged, shrunk, and keyed to the shaft. One end of the shaft is coupled to the generator shaft; part of the weight of the generator rotor is carried by the gear bearing at that end. The turbine end of the gear shaft is extended to carry the worm gear; the worm gear drives the oil pump and the governor.

The gear casing is of fabricated construction and is split at the horizontal center line of the rotor. The bearing seats are welded integral with the lower half of the gear casing. In most installations, cross members and ribs are welded into the casing to form a rigid structure for supporting the rotating elements, the oil pump, and the thrust bearing.

A reduction gear is carefully assembled and aligned for even tooth and bearing loadings to ensure that it will operate with a minimum of maintenance. However, the following paragraphs cover problems that may occur.

Do not allow the gear bearings to wear enough to cause incorrect tooth contact. For proper operation of gears, the total tooth pressure should be uniformly distributed over the total length of the tooth faces. This can only be done by accurate alignment and strict adherence to the designed clearances.

Gear misalignment after prolonged operation is usually traceable to a sudden wearing or wiping of the bearings. This misalignment can be corrected by bearing replacement. However, the installation of new bearings requires a thorough check on the alignment of the gear mesh to assure at least 90-percent contact. The replacement of bearings that exceed tolerances because of normal wear can be detrimental to the operation of the turbogenerator. The gears essentially wear to a conjugate tooth form after prolonged operation. Therefore, replacement of the bearings may cause the gears to operate at different center distances. This may cause a noisy operation. Whenever bearings are replaced, the gear alignment must be checked, and any corrective action should be taken by competent naval repair personnel.

There may be initial pitting of gear tooth faces during the early operation of the unit in service. This may be caused from poor alignment or machining errors in gear tooth profile and helices. The pitting will be localized and will indicate the tooth areas with excessive load concentrations. Such conditions should be corrected, or progressive pitting will continue and can cause general deterioration. Minute high spots in the gear tooth produced by gear hobbing or finishing techniques will also cause initial pitting. However, in this case, the pitting will be distributed over the active face, and the pitting should stop with continued service operation.

You should keep complete and adequate records to properly evaluate the cause of pitting and decide whether or not it is progressive.

Where there is pitting of the elements, metal particles from the pitted areas may be entrapped in the mesh and form raised and depressed areas. To remove the high spots, use a fine grade of carborundum stone. Do not use files or coarse stoning that can damage the tooth contour.

Another source of damage to the gears is foreign particles in the lubricating oil. The continued passage of these particles will destroy the original involute tooth profile. Noisy operation will be caused by the dynamic forces produced by tooth tips contacting the wear shoulder in the flanks of the mating gear teeth. Such noise is most pronounced under lightly loaded conditions when the oil film thickness of the bearing causes the gear elements to operate at minimum center distance. Under heavy loads, the bearing oil film thickness diminishes, and the gears operate under maximum center distance. Under the heavy load conditions, the mating elements withdraw from each other causing the tooth tips of one element to interfere with the wear shoulder of the mating tooth. This will reduce the tooth surface. This type of wear results in the gears having to be replaced or recut.

Foreign particles will also cause high spots, which have a highly polished appearance after prolonged operation. Such areas of heavy contact can eventually cause fatigue failure of the highly loaded portion of the tooth. Only experienced personnel should make corrections to the tooth profile to alleviate these conditions.

Almost all tests, inspections, and maintenance and repair procedures for main reduction gears also apply to turbogenerator reduction gears. Make a visual inspection of the tooth contact of the pinion gear and the main gear periodically and keep a record of the condition of the teeth.

BEARING MAINTENANCE

Chapter 2 of this manual covered propulsion turbines. You will find many similarities between the repairs of bearings in propulsion turbines and those in ship's service turbogenerators. At the same time, you will find that some bearings

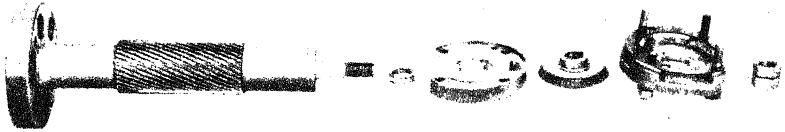

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Figure 4-2.—Collar and plate type thrust bearing.

differ radically between these two kinds of turbines. Therefore, use the following information as a guide, but be sure you go to the manufacturer's technical manual before you begin actual repairs.

At regular intervals, make checks and take clearance readings of turbogenerator journal bearings and thrust bearings, including thrust collars and thrust plates, to help you anticipate the need for repairs.

Most journal bearings are cylindrical and of the steel-backed, babbitt-lined type. They are split on the horizontal center line to help in their installation and removal. Some newer turbogenerators have the pivoted segmental journal bearing. Most journal bearings are prevented from rotating by setscrews or by dowel pins. Journal bearings that are installed and operated properly and receive sufficient preventive maintenance will give many years of satisfactory service. The manufacturer's technical manual and *Naval Ship's Technical Manual,* chapter 244, contain information on the operation and maintenance of these bearings.

On most turbogenerators, the reduction gear casing must be removed before you can reach the pinion gear bearings, the main gear bearings, and the slow-speed thrust bearing. You can remove the forward turbine bearing, the generator pedestal bearing, and the high-speed thrust bearing by lifting the bearing caps and removing the bearings.

On many installations, the thrust bearing (fig. 4-2) consists of a thrust collar and two thrust plates. The thrust collar is locked to the pinion shaft, and the thrust plates are bolted to the casing. The axial position of the thrust collar is determined by the spacer or shim, which is ground to the desired thickness at assembly. The total running clearance between the stationary plates and the rotating element of the thrust bearing should be obtained from the manufacturer's equipment manual. Adjust this clearance by removing or adding shims to the two stationary thrust plates.

The axial position of the generator rotor is maintained by the thrust faces on the gear bearings, which bear against the thrust surfaces machined on the ends of the gear hub. Clearance is adjusted by means of a filler piece between the thrust shoulders of the gear bearings and the gear casing. The low-speed thrust bearing will show little wear under normal operating conditions. The original clearance will change very little in service. If the thrust surfaces do wear, as the result of faulty operation or improper lubrication, they should be replaced or rebabbitted when the total running clearance exceeds the manufacturer's recommendations. Instructions for adjusting the thrust clearance or renewing the thrust bearings are given in the manufacturer's technical manual. Check the applicable blueprints and technical manuals before you attempt any adjustments or repairs to these bearings.

In most installations, to remove the high-speed thrust bearing for inspection or repair, follow these steps:

1. Remove the upper and lower halves of the thrust bearing cover.
2. Remove the four bolts from the outer thrust plate.
3. Remove the outer thrust plate.
4. Remove the locknut and the securing nut from the pinion shaft.
5. Remove the thrust collar and the inner thrust plate.

If the high-speed thrust bearing needs adjustment, follow these steps:

1. Remove the thrust bearing cover.
2. Remove the four bolts from the outer thrust plate.

3. Remove the outer thrust plate.

4. Move the turbine rotor axially in the direction of the generator until the first-stage turbine wheel hits against the nozzles.

5. Set the distance between the face of the thrust collar and the land of the inner thrust plate to the clearance desired (between the first-stage turbine wheel and the nozzle) plus the running clearance of the thrust bearing. Machine the locating spacer to the proper thickness to obtain this clearance.

6. Replace the locating spacer and lock the thrust collar in position on the shaft.

7. Replace the outer thrust plate.

8. Take a thrust clearance reading to determine total clearance of the thrust bearing.

9. If the thrust reading is satisfactory, replace the bearing cover and rotate the unit by hand. If there is no undue friction or binding, the unit may be turned by steam.

After setting the high-speed thrust bearing, set the position of the generator rotor so that the face of the gear is centered with the face of the pinion when both are in a loaded position. Move the turbine rotor in the direction of the generator, and move the generator rotor in the direction of the turbine as far as the thrust bearings will permit; set the gear rotor in this position and obtain the proper clearance by using the proper thickness of shims behind the thrust shoulder of the gear bearings.

On turbogenerator installations that use a Kingsbury thrust bearing, carry out the tests, inspections, maintenance, and repairs in the same manner as those for main propulsion turbines. The procedure is described in the manufacturers' technical manuals and in *Naval Ships' Technical Manual,* chapter 244.

LUBE-OIL SYSTEM MAINTENANCE

Oil pressure to operate the constant-speed governor and lubricate the bearings and gears is supplied by a gear type of pump (view A, fig. 4-3). This pump is located in the base of the gear casings and driven from the low-speed gear shaft.

The separate hand-operated oil pump (view B, fig. 4-3) used to supply oil to the bearings and to the valve gear for starting is located on the gear casing.

Some ships include a third oil pump driven by an electric motor. This pump, mounted on the generator foundation, supplies lube oil to the generator while it is being started

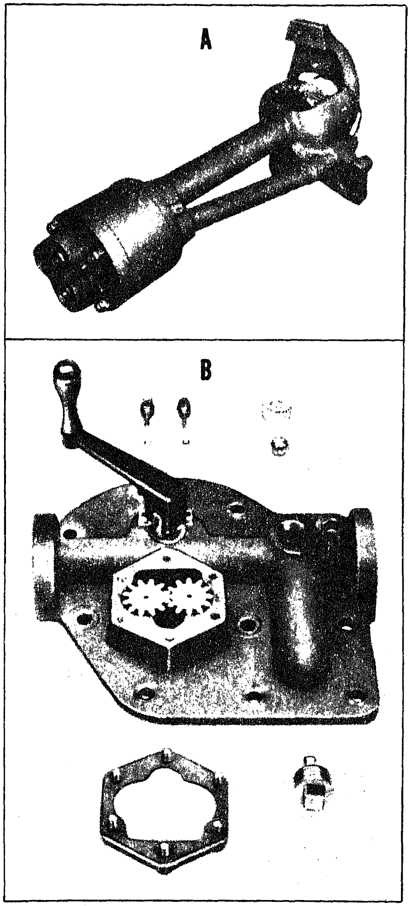

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Figure 4-3.—A. Main oil pump. B. Hand-operated oil pump.

or secured. It is normally started and stopped manually. The pump may also be used as an emergency pump. Once the generator is running, the electric pump may be set so that if the oil pressure falls to a predetermined point (below normal), a pressure-sensing device

located in the oil system will start the electric pump.

A system of oil piping conveys the oil to the speed-governing mechanism and the bearings and gears. A diagram of the oil piping can be found in the manufacturer's technical manual.

All of the oil supplied to the bearings, except that supplied by the hand pump before starting, passes through the oil manifold and the strainer. The strainer assembly is of the duplex type; the shift lever diverts the oil to only one strainer at a time. The lever carries a notation or an arrow to enable the operator to know which strainer is in use. The arrow or notation points to the strainer in use, and all oil passes through this element. A spring-loaded relief valve and a hand valve are built into the manifold. The relief valve is set to relieve excess pressure back to the sump. The hand valve controls the flow of oil to the gear and bearings. It is slotted so that all oil flow cannot be shut off. The hand valve should be set to maintain about 8 to 10 psig on the lube-oil system.

If the oil supply to the bearings is interrupted, stop the unit immediately and then take the necessary steps to restart the oil circulation. These steps may include any one, or a combination of, the following:

- Clean the strainers.
- Repair any broken line.
- Remove any obstructions from the line.
- Add oil to the sump tank.
- Increase the oil pressure by increasing the setting of the relief valve.

If a bearing overheats, slow down the unit but keep it turning over at a low speed until the bearings are cool enough to prevent the bearing metal from adhering to the shaft.

If the oil pressure falls below normal, immediately examine the bearings, the lines, the strainers, and the oil level in the sump tank. If temporary repairs cannot be made satisfactorily with the unit operating, the unit must be secured.

There are several causes for oil leakage from a turbogenerator. The majority of these causes can be corrected by operating personnel. The following list shows causes of leakage with corrective measures to be taken:

1. If oil leakage occurs where a shaft emerges from a casing, the oil seals or deflectors may be excessively worn or damaged and must be replaced to stop the oil leakage.

2. The oil return holes may become clogged with residue from the oil. As the bearings wear and the holes become clogged with dirt, a greater quantity of oil than the holes can accommodate will pass through the bearings. If the bearings are badly worn, the only remedy is to fit new bearings. When the bearings are disassembled for inspection or overhaul, clear the oil passages and oil return holes of all sediment.

3. If the relief valve setting is too high, the oil pressure will be excessive and may cause oil leaks at the bearing ends. You can slightly reduce the relief valve setting to allow some of the oil to be bypassed back to the sump tank.

4. Oil leakage frequently occurs at flanges in the discharge piping. In some instances, you can tighten the flange to stop the leak. In others, you must renew the gasket. In extreme instances, you must take apart the flanges and machine the surfaces true.

When the turbogenerator is operating, clean the lube-oil strainers at least once each watch. Excessive pressure drop across the strainer indicates the need for cleaning. Two strainers are installed for each unit, but only one strainer is in the operating position. The idle strainer can be removed and cleaned. When cleaning a strainer, take care to remove any metal particles adhering to the magnets in the strainer basket. When replacing a strainer, ensure that the inner circular face is against its proper shoulder. If the strainer does not readily fit in the manifold body, do not try to tighten the cover plate; fit the strainer properly against its shoulder.

After putting the cover plate in place, fill the idle strainer with oil. To do this, open the vent and turn the transfer valve slightly toward the idle strainer until oil comes out of the vent. After you have closed the vent valve, the strainer is ready to be put in service.

Any change in the oil temperature drop through the oil cooler when all other conditions remain the same indicates that the water or oil side of the cooler requires cleaning. Even without this indication, the oil cooler tube bundle should be cleaned at regular intervals. To clean the cooler, follow these steps:

1. Turn the cooler bypass valve to the full bypass position. Shut off the water to the cooler. Drain the water side and then the oil side of the cooler.

2. Remove the main head and the floating (lower) head.

3. Remove the gland and the packing.

4. Press upward on the floating (lower) tube sheet. Grasp the main tube sheet when it passes out of the shell and draw the tube bundle straight up, taking care not to let it get out of direct line with the cooler bore and thus damage the baffles.

5. Clean the external surfaces of the oil cooler with a jet of hot water. Clean the internal surfaces of the tubes with a round bristle brush (never use a wire brush for this purpose). Clean the internal surfaces while they are still wet. If the surfaces are allowed to dry, the saltwater deposits will be difficult to remove.

6. In replacing the tube bundle, take care that the baffles do not catch on the shell, as this will cause them to carry the entire weight of the tube bundle.

7. Vent the air from the water and oil circuits after circulation has been started.

8. When the cooler is put in use (after reassembly), carefully check the gaskets and packing for leaks. If there are no leaks, the cooler is ready for routine use.

All turbine-driven generators have a lube-oil low-pressure alarm. The alarm contactor is located in the lube-oil line leading to the bearings. The contactor is connected to an audible alarm and to a signal light. The contactor will close an electrical circuit to the alarm when excessively low lube-oil pressure occurs. The circuit is closed when the unit is not in operation. Therefore, a manual switch must be opened to keep the alarm from sounding. When the unit is brought up to speed, the manual switch must be closed to make the alarm operative.

The contactor is set at the factory to operate when the oil pressure drops to 4 psig, and this setting should be maintained. Follow the instructions contained in the manufacturer's technical manual when making any adjustment to the contactor.

There are at least two pressure gauges to indicate oil pressures throughout the system.

The high-pressure gauge indicates the oil pressure delivered by the pump. This is the pressure that is applied to the governor and to the oil strainers. This gauge is labeled OIL PUMP PRESSURE; and the normal reading is from 50 to 100 psig, depending on the type of governor used.

The low-pressure gauge indicates the oil pressure in the lube-oil lines to the bearings and the reduction gears. This gauge is labeled BEARING OIL PRESSURE, and the normal reading for this gauge is about 8 to 10 psig.

ALIGNMENT

Successful operation of the turbogenerator set requires accurate alignment of the entire unit. This requires accurate setting of the gear casing, turbine casing, and adjustment of bearings. This is essential to obtain satisfactory tooth contact and proper load distribution on the bearings. It is also necessary that when the pinion and turbine shafts are coupled together that they run true with one another. Incorrect alignment may cause vibration, unsatisfactory contact of the gear and pinion teeth, unsatisfactory operation, and, finally, complete failure of the unit.

Under normal circumstances, turbogenerators will be aligned by shipyard, tender, or repair ship personnel. If the services of a shipyard, tender, or repair ship are not available, the following checks may be made by the ship's force, using these steps:

1. Check all foundation bolts to see that they are tight.

2. Check tooth contact by applying very thin layers of prussian blue to several gear teeth and applying red lead to several pinion teeth. Next rotate the pinion in a clockwise direction (when looking at the unit from the turbine end). The contact markings should cover at least 90 percent of the length of the tooth and be equally heavy at both ends of the helix.

3. If the tooth contact is unsatisfactory, you can determine the extent of bearing wear by measuring the crown thickness of the bearings. Measure the clearances of the high-speed and the low-speed thrust bearings.

4. If it is found that one of the pinion bearings or one of the main gear bearings is worn more than .002 inch more than the other bearing, replace or restore the bearings to design clearance. If the crown thicknesses of these bearings are satisfactory and misalignment is suspected, the units will have to be realigned by shipyard, tender, or repair ship personnel. The designed and maximum clearances of bearings are shown on applicable blueprints and given in the manufacturer's technical manuals. If blueprints and technical manuals are not available, it is recommended that the limits given in *Naval Ships' Technical Manual,* chapter 244, be followed. These limits are to be used as a guide; bearings

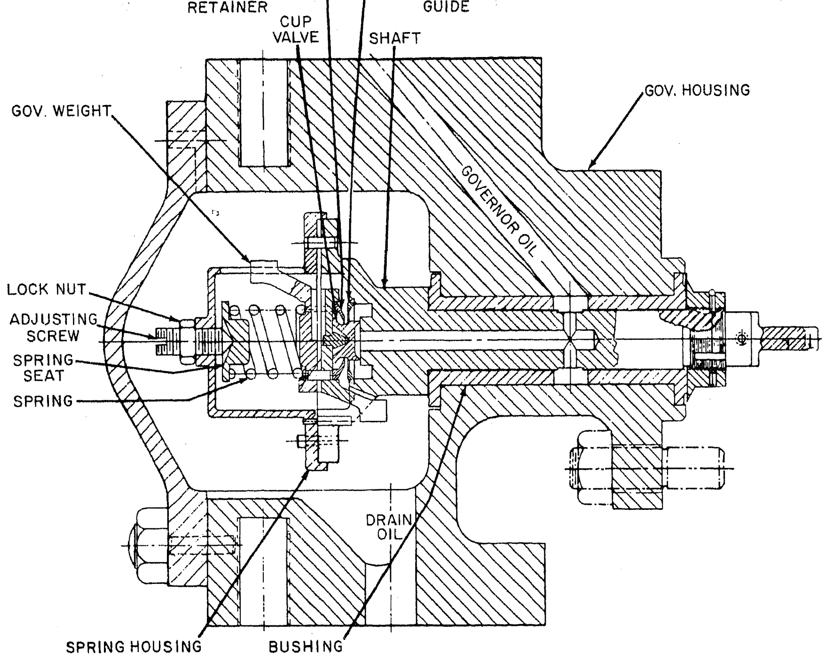

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Figure 4-4.—Governor.

should be renewed, or other applicable repairs should be made, if a smaller amount of bearing wear causes vibration, misalignment, or other abnormal operating conditions.

CONTROL AND SAFETY DEVICES

Turbine-driven generators are equipped with the following control and safety devices:

- A constant-speed governor
- An overspeed trip
- A manual trip
- A lube-oil low-pressure alarm
- A relief valve
- A sentinel valve
- A back-pressure trip
- A gland seal steam regulator

Maintenance consists mainly of keeping all moving parts free of paint, rust, and dirt so that there will be no undue binding or friction. The governor is set at the factory, and the setting should not be changed. Damaged governors should be sent to the factory for repair and adjustment.

Any change in speed range or regulation should be made by adjusting the governor spring

tension. The tension is set properly at the factory and should not be changed unless absolutely necessary. *Regulation* is a term used to express the change in speed that occurs with a change in load. Regulation is usually stated as a percent change in speed that occurs when passing from no load to full load and is based on full-load speed.

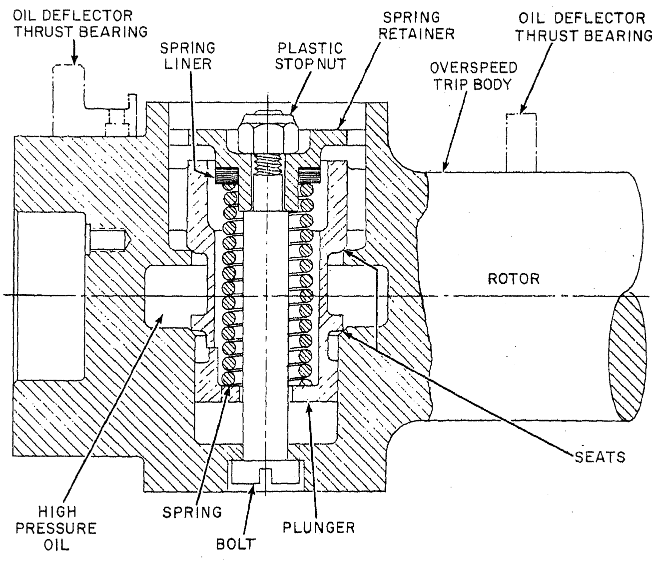
Figure 4-4 shows one type of governor used on Navy ships. A constant-speed (speed-regulating) governor is defined as a governor which controls and regulates the admission of the steam to a turbine. In doing so, it automatically maintains the speed of the turbine at a predetermined rate under all conditions of load and exhaust pressure within the limits of design of the turbine. The governor shaft is located horizontally and is driven directly from the turbine rotor shaft through the overspeed trip body. Governors of this class are of the hydraulic relay type. They are centrifugally controlled, and lubricating oil is used as the relaying medium for the actuating force.

The turbine governor is set at the factory to operate at a predetermined rate with tolerance. Do not make adjustments or repairs on a constant-speed governor without first carefully checking the manufacturer's technical manual for details on maintenance.

The overspeed trip is a device that automatically releases the operating oil pressure under the throttle valve operating piston. This allows the piston spring to close the valve. The mechanism includes a trip of the eccentric weight shaft type that functions as an oil release valve and is mounted on the thrust end of the turbine rotor. One type of overspeed trip for turbo-generators is shown in figure 4-5.

At the predetermined speed for which the device is set, the centrifugal force overcomes the spring resistance. The plunger moves outward, opening to drain the throttle valve operating oil from the cavity formed under the plunger. This mechanism opens to drain the operating oil line leading to the throttle valve operating cylinder, and loss of oil pressure causes the turbine throttle valve to be closed by the loading spring.

Once the turbine unit has been tripped through the overspeed trip mechanism, normal turbine



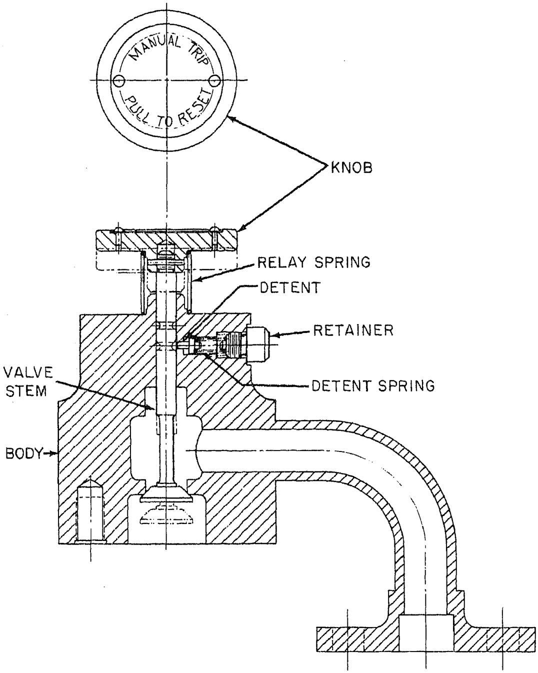


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Figure 4-6.—Manual trip.

operation cannot be resumed until the throttle valve handwheel has been fully closed. The manual trip mechanism should be in the reset position.

Overspeed trips are set at the factory and should be trouble free. If for any reason the plunger should hang up or the tripping speed should change so that an adjustment is required, disassembly will be necessary.

The manual trip (fig. 4-6) is used to stop the flow of steam to the turbine in an emergency. It is also used to secure the unit in a normal manner.

Under normal operating conditions, the parts are held in the latched position by the spring-loaded detent that fits into circumferential grooves machined in the valve stem. The detent is ready to operate by depressing the knob. The oil supply to the throttle valve is metered so that the oil can be drained faster than it can be supplied. Whenever any of the protective devices are activated, the resulting oil pressure drop permits the spring to close the throttle valve.

To reset the manual trip after if has tripped and closed the throttle valve, proceed as follows: Turn the throttle valve handwheel to the CLOSED position. Manually place the tripping mechanism in the CLOSED or RESET position. This closes the oil drain and allows oil pressure to build up, thus permitting the throttle valve to open when the handwheel is turned in the open direction.

The trip mechanism is designed and built to give trouble-free service, under normal operation, for the life of the unit. However, if foreign matter gets into the lubricating oil, it may score

the valve or become lodged under the valve and interfere with its operation. If the valve will not close tightly, try to free it with ordinary flushing by tripping the unit several times. If the valve cannot be freed in this manner or the valve becomes scored, the mechanism will have to be removed from the unit, taken apart, and manually cleaned and inspected. To do this, consult the manufacturer's technical manual for details.

The lube-oil low-pressure alarm is a safety device installed to warn the operator when the lube-oil pressure drops to a dangerously low point. The operation of this device is described earlier in this chapter under the heading Lube-Oil System Maintenance.

Three devices are used to protect the turbine against excessive exhaust pressure: a sentinel valve, a back-pressure tripping device, and a relief valve.

The small (usually one-half inch) sentinel valve is mounted on the upper half of the exhaust casing to warn the operator of excessive exhaust pressure. The valve is spring-loaded and set to function at 2 psig. This setting should be maintained.

The back-pressure trip (fig. 4-7) is set at the factory to function at 5 psig. This setting should not be changed.

The relief valve is spring-loaded and mounted on the exhaust end of the turbine, which permits the turbine to exhaust through it.

The relief valve is normally set to open at 10 to 15 psig (5 psig above the setting of the back-pressure trip). Most relief valves are fitted with a water gauge. The presence of water in the gauge indicates that the valve is closed and properly sealed with water.

When a loss of vacuum in the auxiliary condenser occurs, the sentinel valve will lift when the pressure reaches 2 psig. If the deficiency is not corrected and the pressure continues to increase, the back-pressure trip will function to shut down the unit.

Steam exhaust pressure above 5 psig opens the trip valve. Oil then flows through the trip assembly to drain, and the throttle valve closes. The throttle cannot be reopened until the exhaust pressure falls to less than 5 psig. At that time the trip valve closes and the oil pressure is built up under the throttle valve.

In the event that the back-pressure trip fails to function, the relief valve will function at a pressure of 5 psig above the setting of the back-pressure trip.

Loss of vacuum in the auxiliary condenser is the most frequent casualty to turbogenerators. Insufficient gland sealing steam (or complete loss

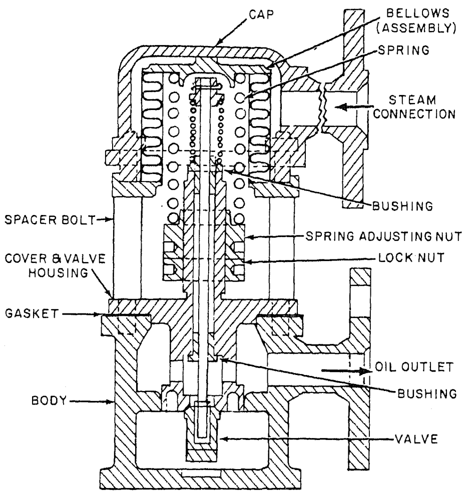

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Figure 4-7.—Back-pressure trip.

of gland sealing steam) is a major cause of this casualty. Some ships have automatic gland sealing steam regulators on turbogenerators (and also on main propulsion turbines) to automatically control gland sealing steam and thus help to prevent loss of vacuum in the condensers.

The two regulator valves, shown in figure 4-8, make up the main component of one type of gland sealing steam system. The self-operated make-up valve (view A, fig. 4-8) is a spring-loaded, diaphragm-operated valve and actuator, requiring steam pressure to close. A handwheel is mounted in the top diaphragm casing for manual operation. The self-operated, unloading valve (view B, fig. 4-8) is a spring-loaded, diaphragm operated valve and actuator, requiring steam pressure to open it. A handwheel is mounted in the top diaphragm casing for manual operation.

Steam of sufficient quantity to seal the glands is taken from the ship's supply line at a variable pressure. It is then reduced to 2 psig, and the supply is automatically controlled by the diaphragm-operated make-up valve. Excess steam, above the amount required by the existing operating conditions for gland sealing, is automatically discharged through the diaphragm-operated unloading valve onto the condenser. The gland sealing steam requirements will vary over a wide range of turbine operating conditions, from light to heavy loads. The sealing steam demands will be greatest while the turbine is being started or operating at light loads. Conversely, the sealing steam demand will be at a minimum while the turbine operates at heavy loads. With the regulating valves properly adjusted, the sequence of their operation is as follows:

With auxiliary steam being supplied to the actuator portion of the valves, the steam enters and flows to one side of the spring-loaded diaphragms. The pressure of the sealing steam flowing through the make-up valve into the header and then to the turbine glands is reflected upon the upper surface of the diaphragm in the make-up valve and the lower surface of the diaphragm in the unloading valve. The diaphragm spring-loadings are adjusted to a predetermined value. When the gland sealing steam pressure in the header becomes high enough to overcome the individual spring-loading, the make-up valve diaphragm and its connected stem and valve plug move downward, which closes the valve. At the same time, the unloading valve diaphragm, stem, and valve move upward to the open position. Then, should the gland sealing steam pressure fall below the operational requirements, this decrease in pressure is reflected upon the upper surface of the diaphragm in the make-up valve and the lower surface of the diaphragm in the unloading valve. Since the counterbalancing steam force has been decreased, the individual valve springs will move the valve stem and plug upward in the make-up valve to open it and downward in the unloading valve to close it.

The regulator valve glands should be kept just tight enough to prevent leakage. Periodically remove the pipe plug in the side of the bonnets and pack the reservoir with graphite bearing lubricant to maintain smooth operation of the main valve rods. The valve is simple, positive, and does not require recalibration during service. For additional information consult the manufacturer's technical manual.

LIFTING TURBINE CASING AND GEAR CASING

The procedure to be followed in dismantling the turbine may be determined by studying the manufacturer's technical manual and the applicable blueprints. The instructions listed here are general. However, most generator turbine casings may be lifted by following these steps:

1. Remove all piping to the throttle valve.
2. Remove the throttle valve.
3. Disconnect the restoring lever from the pilot valve and synchronizing devices.
4. Remove the insulation from the upper turbine casing.
5. Remove the bolts from the horizontal joint of the turbine casing. The bolts in the circumferential joint need not be removed.
6. Remove the upper halves of the high-pressure and low-pressure packing boxes. Remove the packing from the high- and the low-pressure packing boxes.
7. Attach the proper lifting gear, using the pad eyes welded in the overhead and the eyebolts in the casing, and lift the casing. You may use jackscrews to help break the horizontal joint. In most installations, the upper halves of the diaphragms and the diaphragm packing are fastened to the upper half of the casing and will be lifted with it.
8. Use guide pins—a minimum of two, but preferably three.

If the turbine rotor is to be removed, the upper half of the reduction gear casing

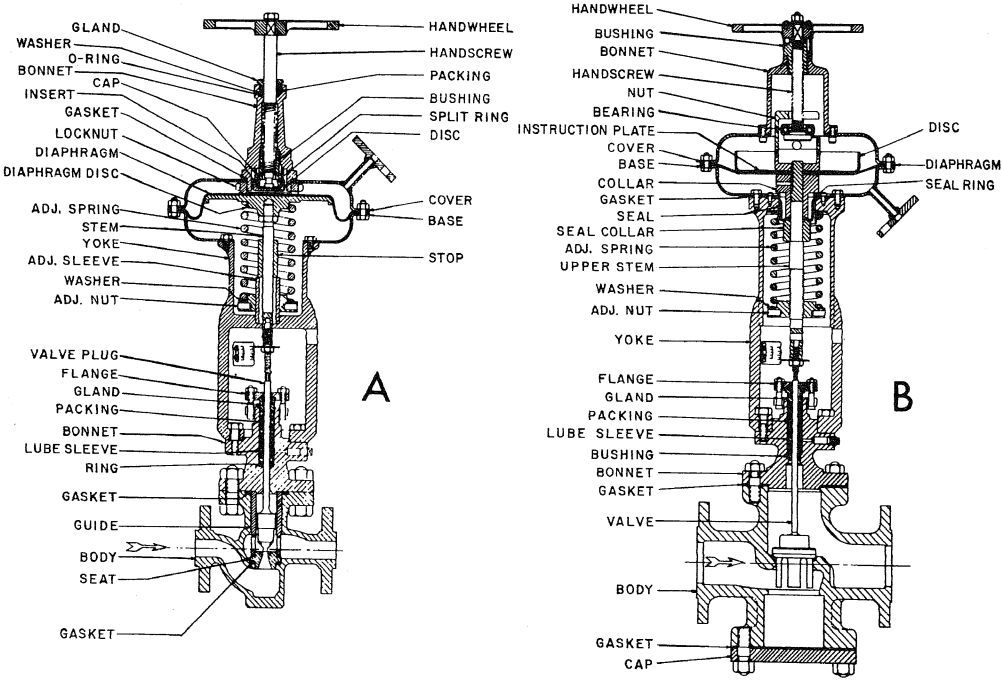

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Figure 4-8.—Gland sealing steam regulators. A. Gland sealing steam make-up valve with actuator. B. Gland sealing steam unloading valve with actuator.

must be removed first. This can be accomplished as follows:

1. Remove the pilot valve body and the synchronizing device.
2. Remove the cover from the high-speed thrust bearing and the two studs that hold the thrust bearing to the upper half of the casing (if applicable).
3. Remove all gauges and thermometers from the upper half of the casing.
4. Remove all parting flange bolts. Remove any end plates that may be bolted to the upper and lower halves of the gear casing.
5. Remove the bolts holding the oil deflector halves together (if applicable).
6. Remove all bolts that connect the upper and lower casing flanges. Then use the jacking bolts to break the joint. If you do not break the joint in this manner, you may distort the casing.
7. Lift the casing by means of the pad eyes, eyebolts, and chain hoists provided for this purpose. Lift the casing straight up to avoid striking the gear.
8. Since the pilot valve remains connected to the governor, be sure to lift the casing high enough to clear the pilot valve.
9. Remove the upper halves of the journal bearings that support the turbine pinion rotor.
10. Remove the high-speed thrust bearing.
11. Lift the turbine rotor and the pinion shaft as a single element.

PREVENTIVE MAINTENANCE

Maintain the turbogenerators and hold systematic inspections and tests at periodic intervals to ensure safe and reliable operation. At the required intervals, run idle turbines with steam (if available) or turn them by hand. Circulate oil through the system by means of the hand pump. Lubricate the trip mechanism and other working parts. Sample the lubricating oil and test it for the presence of water. Check the oil to determine its general condition and purify it when necessary. Operate all relief valves at the required intervals to make sure they will operate when necessary.

Make tests and inspections in accordance with the PMS. The PMS states the minimum number of tests and inspections necessary to assure safe and reliable operation of the equipment. Perform additional or more frequent tests at the discretion

SAFETY PRECAUTIONS

Safety precautions are extremely important and must be strictly adhered to for the safety of operating personnel and to prevent damage to the machine.

Operating instructions and safety precautions for turbogenerators should be posted in the vicinity of the units. You can get more complete information on safety precautions from *Naval Ships' Technical Manual,* chapter 231, and the manufacturer's technical manual furnished with each unit. The following safety precautions are the MINIMUM required:

- Do not operate a turbogenerator that has an inoperative overspeed trip, back-pressure trip, or constant-speed governor.

- Keep all relief valves and the sentinel valve in good operating condition, and keep them set at the pressures specified by the manufacturers.

- Test the exhaust casing relief valve by hand before admitting steam to the turbine.

- Keep the oil sump filled with clean oil at all times.

- Avoid water hammer and damage to turbine blading and thrust bearings by properly draining steam lines and opening steam valves slowly.

- Before putting a turbogenerator in service, test the overspeed trip.

- Before starting a turbogenerator, check to see that it is clear of all foreign matter.

- Do not pass steam through a turbine at rest; admit only enough steam to immediately start the unit rolling.

- Do not allow air to be drawn through the turbine glands when the rotor is at rest.

- Keep the governor operating mechanism, valve stems, and other moving parts clean and free of corrosion.

- Keep oil pressures at the values specified

- Examine and clean the lube-oil strainers at least once each 4 hours of operation, and more often if operating conditions indicate the need for more frequent cleaning. Always ensure that the strainer caps are properly secured before use.

- Do not admit any steam (exhaust or drains) to the auxiliary condenser before an adequate flow of cooling water is passing through the condenser tubes.

- Do not admit steam to the auxiliary air ejectors before the auxiliary condensate pump is started.

- Never operate a turbogenerator that is known to have defective safety devices, defective control devices, or excessive journal or thrust bearing clearances.

- Frequently inspect all fire-main and cooling water lines in the vicinity of the generator for leaks.

CHAPTER 5

HEAT EXCHANGERS AND AIR EJECTORS

As a Machinist's Mate 1 & C, you must know how to maintain the heat exchangers and air ejectors on Navy ships. This chapter covers the general maintenance and repair of main and auxiliary condensers, deaerating feed tanks (DFT), and lube-oil and air coolers. Although smaller heat exchangers are not specifically discussed, the basic information in this chapter will be useful in the maintenance and repair of these other heat exchangers.

This chapter also has information on the operation and maintenance of air ejectors.

Before studying this chapter, you may find it helpful to review heat transfer and classification of heat exchangers. This information can be found in *Machinist's Mate 3 & 2,* NAVEDTRA 10524-F, and in *Naval Ships' Technical Manual,* chapter 254.

MAINTENANCE OF MAIN AND AUXILIARY CONDENSERS

Shipyard, repair ship, or tender personnel are usually responsible for such repair work as retubing condensers and overhauling injection and overboard valves. However, you should have a good understanding of the procedures involved. You should also be qualified to act as a ship's inspector to see that all work is being performed satisfactorily. Machinist's Mates will inspect and clean main and auxiliary condensers, check for leaks and plugged tubes, and operate the units.

INSPECTING AND CLEANING CONDENSERS

Under normal operating conditions, the saltwater side of a main condenser should be inspected in accordance with the planned maintenance system. The steam side should be inspected whenever the inspection covers are removed from the low-pressure turbines.

Conditions may arise that call for more frequent inspections of main condensers. The ship may operate in shallow water or in waters where there are large amounts of seaweed, schools of small fish, or large amounts of oil. When any of these conditions occur, open the condenser for inspection and cleaning.

Carefully maintain the saltwater sides of condensers. This prevents failures caused by deposits on tubes and prevents loss of heat transfer caused by accumulations of these deposits. Inspect and clean the saltwater sides of condensers at the following times:

- Whenever zinc anodes are checked
- Immediately after grounding of the ship
- Whenever the condensers' performance indicates a possibility of tube fouling
- As soon as practical after operating in shallow or polluted water

Before opening the saltwater side of a condenser, read and observe all precautions listed in this chapter and in *Naval Ships' Technical Manual,* chapter 254.

Saltwater Side

Lay-up requirements for the saltwater side of the condensers are divided into the following three conditions:

1. Short-term lay-ups up to 1 week
2. Midterm lay-ups of more than 1 week and less than 4 months
3. Long term lay-ups of 4 months or longer

For short-term lay-ups, the saltwater side should be kept full. Circulate the water once a day for at least 10 minutes by running the circulating pump. If you are unable to circulate

the water for 3 or more days in succession, drain the water and refill with freshwater of potable or feedwater quality. For midterm lay-up, drain the saltwater side and immediately fill it with freshwater of potable or feedwater quality. After the first 2 to 3 weeks, drain the condenser and refill with freshwater again. Thereafter, keep the saltwater side filled with freshwater until the ship returns to operation or until the saltwater side is cleaned. For long-term lay-ups, open the saltwater side and clean it. After cleaning, keep the saltwater side drained.

The general procedures for cleaning the saltwater side condensers are as follows:

1. Clean the tube sheet and the inside of the water box using freshwater and either a stiff nonmetallic brush or plastic scraper.
2. Remove material lodged in tubes with air, a water lance, water gun, high-pressure water jet, or nonmetallic rod or scraper. Do not use abrasive tools capable of scratching or marring the tube surface. Use air and water lances and any other cleaning equipment carefully to avoid damaging the protective film and causing subsequent tube failure. For further information concerning saltwater side cleaning, refer to *Naval Ships' Technical Manual,* chapter 254.

Steam Side

The lay-up requirements for the steam side of the condensers are divided into the following two conditions:

1. Idle periods up to 1 month
2. Extended idle conditions in excess of 1 month

For idle periods, empty the hot wells of the condensers and keep them drained.

For extended shutdowns on all condensers, drain and dry out the steam side as soon as possible after the condenser has been secured. This minimizes condenser shell corrosion. The condenser shell can be dried out with an electrically heated air blower discharging into a hot well opening. After drying, close the condenser openings. Check the condenser shell weekly and repeat the drying process if moisture is found inside.

Whenever the manhole plates are removed from the low-pressure turbine for inspection or maintenance, the steam side of the tubes should be inspected. Check the entire steam side for grease and dirt. If grease and dirt are found, remove them by boiling out the condenser with a solution of trisodium phosphate. Normally, condensers that serve turbines should not require boiling out more frequently than every shipyard overhaul period. Instructions for the boiling-out process may be found in *Naval Ships' Technical Manual,* chapter 254.

TUBE LEAKAGE

Any tube leakage, however slight, will cause serious damage if neglected. The condensate system will become contaminated and cause serious damage to the boiler tubes. It is not unusual for a newly tubed condenser to develop leaks caused by defective tubes or tube sheets or by improper installation. However, if the defects are corrected, the condenser will give years of satisfactory service.

The most common cause of tube leakage is deterioration, which starts at the saltwater side of the tube and proceeds through the tube wall of the steam side. However, leakage may also be caused by deterioration starting at the freshwater side of the tube wall, by a defective joint between the tube and tube sheet, or by cracking of the tube wall or tube sheet.

Impingement Erosion

Seawater flowing into the condenser tubes at high velocity tends to remove the thin protective film of corrosion products adhering to the tube walls. This protective film is replaced at the expense of further corrosion of the tube wall. As the protective film is continually removed and replaced by corrosion products, the tube wall is gradually thinned, and the joint between the tube and the tube sheet is weakened. A saltwater leak ultimately occurs, because of the failure of the tube joint or perforation of the tube wall beyond the tube sheet. This type of attack is generally confined to the region of the tube at or near the inlet end. It is known as impingement erosion, inlet end attack, or bubble attack. The frequency and speed of the attack are influenced mainly by water velocity through the tubes. They are also influenced by the amount of air entrained with the circulating water and by the design of water chests and injection piping.

Tube deterioration caused by impingement erosion of the tube ends can be minimized by proper regulation of circulating water through condensers and by proper venting of water chests.

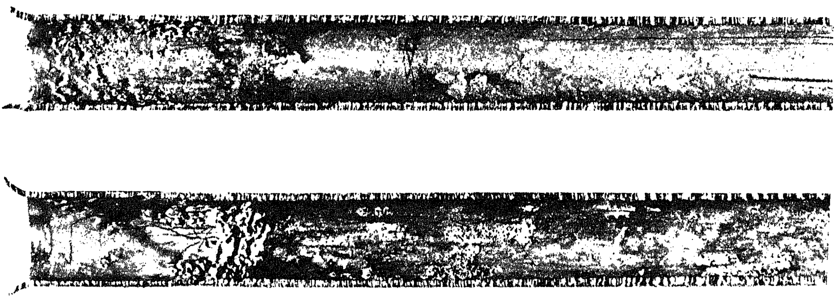

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Figure 5-1.—Tubes damaged by impingement erosion.

Figure 5-1 shows a tube that has been badly damaged at the inlet end by impingement erosion.

If wet steam impinges on condenser tubes at high velocity, the surface of the tubes will rapidly erode. This erosion will eventually perforate the tube wall, and seawater will leak into the condensate. Baffles or distribution pipes installed within the condenser shell prevents direct impingement of water and steam from the auxiliary exhaust line, the recirculating line, and the makeup feed line.

These baffles must be installed in such a way that they do not touch the tubes, since vibration will cause tube failure. If frequent tube leaks occur in the vicinity of a steam or water connection to the condenser shell, it is evidence that the baffling system is defective or that the plant is not being operated properly.

To prevent tube erosion from auxiliary exhaust lines, continuously and thoroughly drain the line. Before you shift the auxiliary exhaust to a condenser, open all drain valves on the exhaust line and take every precaution to ensure that the exhaust line is drained properly. If there is a pocket in the exhaust line that will allow condensate to collect, install a drain to ensure complete drainage of the auxiliary exhaust line.

Testing for Leaks

Seawater leaks cannot always be detected by salinity indicators in the condensate system. The first indication of seawater leaks may be a chloride buildup in the boiler or, when the plant has been secured, in the hot well of the idle condenser.

Ensure that the source of chloride contamination is not in the piping connected to the condensers, rather than the condenser tubes. Pay special attention to sections of the condensate, drain, and makeup feed piping normally under vacuum and located in the bilge area.

A change in circulating water or condenser temperature may cause a slight seawater leak to disappear temporarily, only to recur with a further change in operating conditions.

Several test methods that may be used to detect the source of circulating water leaking into condensers are described in *Naval Ships' Technical Manual,* chapter 254. Use the simplest suitable test first. The procedure for this test is as follows:

1. Drain circulating water from the watersides of the condenser and remove the water box inspection plates.
2. Apply air pressure not exceeding 15 psig to the steam side of the condenser.
3. Slowly fill the saltwater side of the condenser with circulating water.
4. Replace the lower inspection plates as the water level nears the openings.
5. Watch the surface of the water adjacent to both tube sheets for air bubbles indicating leakage.

You will notice a large leak immediately. Detecting smaller leaks will require more time and closer observation. Consider the trim and list of the ship, as well as bowed tubes, when you inspect for leaks.

Under normal conditions, an MM1 or MMC will not be expected to retube a condenser. Because of modern materials and manufacturing methods, condensers seldom need retubing. When they do, special tools and equipment are necessary; and the work is performed by tenders, repair ships, or a shipyard. However, you are responsible for inspecting the job to see that it has been properly completed and tested.

In general, specimen tubes should not be drawn from a condenser or heat exchanger for examination purposes except when removal is specifically directed by NAVSEA or by a Board of Inspection and Survey. However, under the following conditions, tubes may be drawn without NAVSEA authorization:

- When frequent leaks have been caused by tube failures, specimen tubes should be drawn from widely separated parts of the unit in order to establish the general condition of the tubes.

- When several tubes have failed in the vicinity of a steam or water inlet to the condenser shell, specimen tubes should be drawn unless the cause of the failure can be determined by visual inspection of the steam side of the unit.

Carefully mark samples from the most badly deteriorated tubes to show the top and the bottom of each sample and the location from which the sample was drawn. Cut the samples into lengths of about 12 inches, and identify them as to position along the length of the tube. Split them lengthwise, and open them to permit ready examination. Send these samples to NAVSEA together with a complete report of the conditions found.

Retubing Request

Before any work is begun in retubing a main condenser, authorization must be obtained from NAVSEA. When a retubing request is submitted, the following information must accompany the request:

- The condenser involved and the date when the condenser was last tubed or retubed.

- Whether or not any of the tube leaks were caused by improperly expanded or packed tube joints. type of tube failure (usually determined when the failed tube is drawn and split for inspection), the conditions of operation, and any known or suspected contributory causes.

- The source of supply of the tube, if known.

- The position in the tube bundle of each failed tube and of each specimen tube drawn for inspection.

- The part(s) of each specimen tube where defects were found (external, internal, top, bottom, ends, and so forth); to meet this requirement, tube ends must be marked before removal so that the top can be located.

- The tube, tube sheet, and water box materials, and the type of tube joints employed.

- The condition of the zincs; the frequency of renewal, the frequency of scaling, and the method of cleaning the zincs (when installed).

- The method and frequency of cleaning the tubes.

- Whether or not the unit was kept thoroughly vented during its operation.

- Whether or not the tubes were cleaned and blown out whenever seawater was drained from the unit.

- If severe deterioration of tube ends and tube sheets is visible and photographic equipment is available, photographs of the tube sheets should be taken and sent to NAVSEA for information purposes.

- The extent of work considered necessary. Partial retubing of a condenser is not considered economical, except that authorization is sometimes given for retubing one pass of a two-pass condenser.

- A list of materials required, specifying length, outside diameter, wall thickness, and type of tube joints at both inlet and outlet ends.

- Recommendations and comments by authority endorsing the request.

Forces afloat or a shipyard may retube auxiliary condensers and other small heat exchangers

retubing to NAVSEA. Include the same information that is required for requests for retubing main condensers.

Removing Tubes

When a main condenser is to be retubed, the following procedure is the most efficient one for removing the old tubes. Cut them inside the shell with a power-driven saw or other suitable cutting tool. Then drive the ends of the tubes out of the tube sheets with a drift. Figure 5-2 shows a drift suitable for tubes that have a 5/8-inch outside diameter and a wall thickness of 0.049 inch. If you have problems in removing expanded tubes, you may have to ream the expanded ends so that only a thin shell remains at the outer surface of the tube.

If you use a reamer, it should have a pilot that closely fits the inside bore of the tube. Ensure that the reamer does not touch or mar the surfaces of the tube holes in the tube sheet. Figure 5-3 shows a reamer suitable for this type of work.

Regardless of the method used to remove the tubes, do not damage the tube holes in the tube sheets in any way.

Renewing Tubes

Before installing replacement tubes, make a very careful examination of the interior parts of the condenser shell. If there is any reason to believe that the joints between the tube sheets and the condenser shell are not in perfect condition, remove the tube sheets. True the flanges and install new gaskets. Remake joints between the stay-rods and the tube sheets and repack the stay-rods. Should any defects be found after the new tubes are installed, you may need to cut out the newly installed tubes to correct the defect(s).

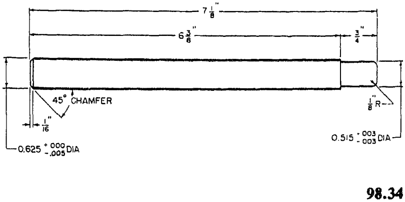

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Figure 5-2.—Drift for driving tube ends from tube sheets.

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Figure 5-3.—Reamer for removing expanded tube ends.

Only copper-nickel tubes conforming to NAVSEA specifications may be used in condensers that are saltwater cooled. These tubes are furnished in stock lengths and must be cut to proper length by the installing activity. The usual practice is to cut the tubes in lengths about one-eighth inch longer than the distance between the outside faces of the tube sheets. After installation, finish the tubes to the exact length by using an air-driven end mill or surface grinder.

EXPANDING TUBES.—Nearly all condensers installed aboard naval ships have the inlet tube ends expanded in the tube sheet, forming a metal-to-metal joint. In many installations, the outlet tube ends are also expanded. If the condenser tubes are expanded at both ends, it is common practice to provide one or more grooves, or serrations, in the tube holes. This increases the holding power of the expanded tube joint. Thoroughly clean out these grooves and remove any burrs before installing new tubes.

Tube expanders used in retubing condensers and other heat exchangers must meet Navy specifications. Forces afloat or shipyards should not use any type of tube expander except those furnished to the ship by the manufacturer and approved by NAVSEA. The tube expander rolls should be tapered to correspond with the taper of the expander mandrel to ensure parallel expansion of the tube walls. The inner ends of the rolls should be suitably rounded off to form a torpedo-shaped end. This prevents ridging and cutting of the tubes at the inner end of the expanded joint. A tube expander must be properly set for a given job. To do this, you must ensure that the overall length of the rolls are not less than three-sixteenths inch nor more than five-eighths inch greater than the thickness of the tube sheet into which the tube is expanded. Adjust the expander so that the expanded portion of the tube does not extend completely through the cylindrical

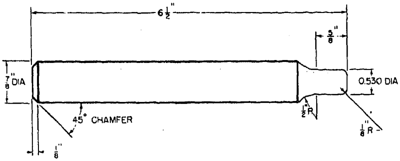

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Figure 5-4.—Tool for flaring main condenser tubes.

portion of the tube sheet hole; leave about one-eighth inch of the tube at the inner end of the tube hole unexpanded. If the tubes are expanded completely through the tube sheet, the part of the expanded joint that extends into the condenser and beyond the support of the tube hole will bulge, and it will be extremely difficult to remove the tubes later.

After the tubes are expanded, bell or flare the inlet ends of the tubes to an outside diameter (OD) of not more than 3/4 inch for 5/8-inch OD tubes and not more than 7/8 inch for 3/4-inch OD tubes.

Drive flaring tools into the tube end so hard that the wall of the tube is appreciably thinned or cut. Figure 5-4 shows a flaring tool that is suitable for 5/8-inch OD tubes that have a wall thickness of 0.049 inch. It is good practice to mill or grind the projecting flared ends of the newly installed tubes flush with the tube sheet surface. This provides a smooth entrance for the circulating water flowing into the inlet ends of the tubes. It is not necessary to flare the outlet ends of the tubes; the tube outlet ends may be allowed to project one-sixteenth inch from the face of the tube sheet surface.

PACKING TUBES.—Use flexible metallic packing, in accordance with Navy specifications, to pack the outlet ends of packed condenser tubes. Expand the inlet ends of the tubes into the tube sheets before packing the outlet ends. Completely remove the old packing and thoroughly clean the threads and serrations of the glands of all foreign matter.

When stuffing box glands are three-fourths inch deep, the proper packing consists of two fiber rings and two metallic rings. To assist in the installation of packing, insert a loading pin (fig. 5-5) into the outlet ends of the tubes.

After the loading pin is inserted, place a fiber packing ring on the pin and drive it to the bottom of the stuffing box. Next, place a metallic packing ring on the loading pin and caulk into the packing box with three or four light hammer blows to cause the metal to flow into the threads of the gland. Then repeat these operations; i.e., insert another fiber ring and another metallic ring in the same manner. Caulk each ring in place separately. If the depth of the stuffing box is greater than three-fourths inch, install an additional metallic ring. Caulk it into place to completely fill the stuffing box with packing.

If the stuffing box is five-eighths inch deep instead of three-fourths inch deep, only three rings of packing can be used. Caulk one metallic ring in place, followed by a fiber ring and a second metallic ring. Never flare or expand or bell the outlet ends of packed condenser tubes.

When a condenser is retubed, test the tubes for leaks. The test is made by filling the shell with warm water. (Warm water must be used to avoid

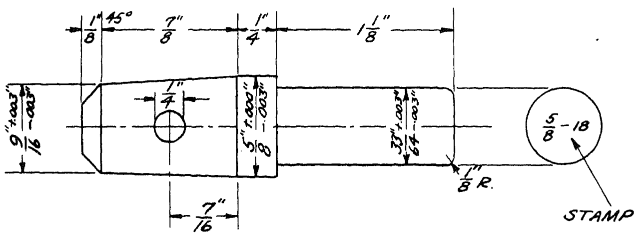

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Figure 5-5.—Loading pin for packing main condenser tubes.

condensate forming on tubes and tube sheets and giving a false indication of leaking.) If any leaky tubes are found, recaulk them with light hammer blows applied to the caulking tool.

The amount of force used in striking the caulking tool with the hammer is extremely important. If too little force is used, the joint will leak. If too much force is used, it will "neck" the tube end. The tube end will then be held too tightly in the packing gland to allow proper movement during normal expansion. When the necked tube does move through the packing, the joint will leak.

CARE OF IDLE CONDENSERS

The condensers on most naval ships are either expanded at both ends or expanded at the inlet end and packed at the outlet end. These units should normally be drained and kept empty when they are secured. The lay-up procedures were covered earlier in this chapter.

Whenever the saltwater side of a condenser is drained, take special care to ensure the tubes do not have water anywhere along their lengths. Tubes frequently become sagged. Water trapped in these pockets at one or more points along the tube length, if allowed to remain in a drained condenser, will gradually evaporate. The impurities left behind will corrode the tubes at these points. In time, this will cause a tube failure. This corrosive action is particularly acute when condensers are drained of highly polluted water. The best way to avoid this type of tube deterioration is with an ample supply of freshwater available from a pier. Water-lance each tube with freshwater to wash out the polluted water and remove foreign matter from the tubes. Following the water-lancing operation, air-lance the tubes and leave them dry until the condenser is again put in service.

If sufficient freshwater is not available for water-lancing, air-lance each condenser tube and leave it completely dry; then inspect the condenser daily. If any water tends to collect in the tubes, through condensation from the atmosphere, repeat the air-lancing operation as necessary to avoid the formation of water pockets at low points along the tubes.

When a condenser is secured, keep the steam side empty.

SAFETY PRECAUTIONS FOR CONDENSERS

When opening a main condenser for cleaning or inspection or when testing a main condenser, you must use the following safety precautions. When carried out properly, they will help prevent casualties to personnel and machinery.

1. Before the saltwater side of a condenser is opened, close all sea connections tightly, including the main injection valve, circulating pump suction valve, and main overboard valve. Tag them to prevent accidental opening.
2. On condensers with electrically operated injection and overboard valves, open the electrical circuits serving these motors and tag them to prevent these circuits from being accidentally energized.
3. Before a manhole or handhold plate is removed, drain the saltwater side of the condenser by using the drain valve provided in the inlet water box. This ensures that all sea connections are tightly closed.
4. If practical, replace inspection plates and secure them before you stop work each day.
5. Never subject condensers to a test pressure in excess of 15 psig.
6. When testing for leaks, do not stop because one leak is found. Check the entire surface of both tube sheets, as there may be other leaks. Determine whether each leak is in the tube joint or in the tube wall so that the proper repairs can be made.
7. It is possible that hydrogen or other gases may be present in the steam side or the saltwater side of a condenser. Do not bring an open flame or tool that might cause a spark close to a newly opened condenser. Do not allow personnel to enter a newly opened condenser until it has been thoroughly ventilated and the space declared safe by a gas-free engineer.
8. Drain the saltwater side of a condenser before flooding the steam side, and keep it drained until the steam side is emptied.
9. The relief valve (set at 15 psig) is mounted on the inlet water chest. Lift it by hand whenever condensers are secured.
10. If a loss of vacuum is accompanied by a hot or flooded condenser, slow or stop the units exhausting into the condenser until the casualty is corrected. Do not allow condensate to collect in condensers and overflow into the turbine or engines.
11. Lift condenser shell relief valves by hand before a condenser is put into service.
12. Do not retain any permanent connection between any condenser and water system that could subject the saltwater side to a pressure in excess of 15 psig.

13. Do not retain any permanent connection that could allow salt water to enter the steam side of the condenser.

14. Test the main circulating pump bilge suction when so directed by the engineer officer. To conduct this test, you generally need only to start the main circulating pump, open the bilge suction line stop or check valve, and then close the sea suction line valve until it is about three-quarters closed or until the maximum bilge suction capacity is obtained.

OPERATION OF CONDENSERS

Relatively few casualties occur to main condensers compared with the number of casualties that occur to some units of naval machinery. The most frequent casualty to a main condenser is a reduction in vacuum. Inadequate vacuum or any other casualty to a main condenser will cause failure of the propulsion turbines to produce full power or cause complete failure of the main engines. Operate condensers to obtain a vacuum in accordance with design requirements and to obtain maximum service life and reliability of the equipment.

CIRCULATING-WATER CONTROL

When the gate valve in the circulating-water overboard piping is used to regulate the water flow through the condenser, this valve should be kept at least one-quarter open. If a gate valve used for throttling is closed more than three-quarters, the gate is likely to pound against the seat rings and damage the valve so that it will not be watertight when closed. There may be some erosion of the valve gate and seating rings if the valve is continually used for throttling. Whenever a ship is drydocked, inspect the injection and overboard valves to be sure they are in good working condition and watertight.

While an overboard valve is throttled, a sudden increase in power will cause a slight loss in vacuum. The loss will not usually be serious and can be corrected by opening the overboard valve. In the event of an unexpected demand for full power astern, open wide the overboard valve as quickly as possible.

VACUUM CONTROL

Under normal operating conditions, you should operate condensers fitted with scoop injection to maintain the maximum vacuum obtainable and with the main injection and overboard valves wide open, except under the following conditions of operation under full power and cruising speeds.

When making FULL POWER or speeds closely approaching full power, under cold injection conditions, the condenser can usually obtain a higher vacuum than the low-pressure turbine can use effectively. In the average installation, as the full-power vacuum becomes higher than about 1 inch of mercury above the vacuum for which the low-pressure turbine was designed, the extra steam required to heat the condensate will outweigh the added economy of turbine operation that is gained by the higher vacuum. The designed full-power vacuum for any turbine installation may be found in the manufacturer's technical manual.

When operating at cruising speeds, the turbines can generally make effective use of the maximum vacuum of which the condensing plant is capable. However, with cold injection at low power, the condenser can produce a vacuum higher than that at which the air-removal equipment will handle the normal air leakage into the system. Under standby conditions, very little steam is discharged to the condenser. During standby most installations fitted with properly functioning air ejectors will produce a maximum vacuum of about 29 1/2 inches of mercury with cold injection temperature. Under these conditions, the average installation fitted with air pumps operated at normal speed will produce a maximum vacuum of 28 to 29 inches of mercury, depending on whether or not augmenters are fitted. When the ship is cruising at low and medium powers with cold injection, the condenser vacuum tends to approach the maximum of which the system is capable under standby conditions with that injection temperature. The air-removal equipment then tends to become unable to free the condenser of normal air leakage. The air collects in the condenser, tending to insulate the tubes from the condensating steam and to settle into the hot well. At that time, there is usually a noticeable increase in the condensate depression. You should try to avoid loss of economy and absorption of air into the condensate under these conditions. To do so, throttle the flow of circulating water as necessary to limit the vacuum to about 0.2 inch of mercury less than the maximum obtainable with full flow of circulating water or as necessary to reduce the condensate depression to normal. If the condensate depression remains between 0 and 2 degrees

under low-power operation at medium injection temperature, the air-removal equipment is ridding the condenser of air leakage, and throttling of circulating water is unnecessary.

When there is a loss of vacuum in a condenser, it means that the units of machinery exhausting into the condenser are out of commission. Air leakage into a condenser decreases the vacuum obtainable and increases the condensate depression. If air leakage becomes excessive, the units of machinery exhausting into the condensers will have to be secured.

Maintaining proper vacuum is one of the more important duties of engine-room watch standers. This training manual cannot cover all of the reasons for loss of vacuum. However, since air leakage into the vacuum system is the most common cause of vacuum loss, we will cover some of the methods of conducting air tests.

There are many ways in which air can leak into a system under vacuum. Every flange, gasket, connection, packing gland, and valve bonnet that connects to the vacuum system can be a source of air leakage. Air leaks can be very difficult to locate. Some of the most common methods used to find and stop leaks are covered here:

- Fill the condenser and the connected piping, which is normally under vacuum, with freshwater. Then using compressed air to build up a pressure of 5 to 10 psig in the turbine casing, check the condenser and piping for water leaks. A water leak indicates an air leak.

- Use the candle flame test. With the system under vacuum, hold a lighted candle to all areas where leaks are suspected. If the candle flame is held close to a leak, the vacuum will draw the flame toward the leak.

- Apply soapsuds to areas where leaks are suspected. The soapsuds solution should be prepared so that it has the consistency of liquid hand soap and will work into a lather on a brush. With the condenser shell subjected to a 5-pound air pressure, apply the lather all the way around the joints. Check the joints for bubbles. Lather doubtful spots a second time. If you are still in doubt about the existence of leaks, lather the doubtful spots several times.

- Use the air test. If the test is to be conducted on a main condenser, the procedure is as follows:

Start a lube-oil service pump; engage and start the turning gear. Cut in gland sealing steam to the main turbines. Next, build up a pressure of 5 to 10 psig throughout the vacuum system. Listen carefully for air leaking out of the system. This method is more effective if all the vents and machinery in the engine room, except the lube-oil pump and turning gear, can be secured. This will reduce noise, which is important since this method depends entirely on detecting the sound of air escaping.

- When testing for air leaks, investigate all places where an air leak is possible. Condensers have many fittings and joints that should be examined as far back in the lines as vacuum exists under any operating conditions.

- Leaks at flanged joints and in porous castings can usually be stopped with an application of shellac when the condenser is under vacuum. If shellac is used, consider it a temporary repair. Make permanent repairs as soon as time and the ship's operation permit.

- In installations where the condenser supports the turbine, main exhaust trunk flanges are generally fitted with a flange grooving system. This provides for pressure pumping with a suitable sealing compound. If the shell relief valve (or its connection to the condenser shell) is suspected of leaking, it can, in most installations, be tested in place. Most shell relief valves are fitted with a small-gauge glass to permit introduction of water above the disk as a test for tightness.

OTHER HEAT EXCHANGERS

Condensers are but one type of heat exchanger found in engine rooms. Lube-oil coolers, air coolers, and deaerating feed tanks (DFT) are other heat exchangers that Machinist's Mates maintain. The following sections have information on maintaining these units.

DEAERATING FEED TANKS

Additional information on the principles and operation of DFTs may be found in *Naval Ships' Technical Manual,* chapter 9562.

General interaction on operation and maintenance of the units are discussed in this chapter. For more detailed information in any specific unit, refer to the manufacturer's technical manual.

Operation of a Deaerating Feed Tank

DFTs remove gases from the feedwater by using the principle that the solubility of gases in feedwater approaches zero when the water temperature approaches the boiling point. During operation, steam and water are mixed by spraying the water so that it comes in contact with steam from the auxiliary exhaust line. The quantity of steam must always be proportional to the quantity of water; otherwise, faulty operation or a casualty will result.

During normal operation, the only control necessary is to maintain the proper water level. This is done with automatic water level control valves. (Some of the older ships have manual water level control valves.) If the water level is too high, the tank cannot properly remove the air and noncondensable gases from the feedwater. A low water level may endanger the main feed booster pumps, the main feed pumps, and the boilers.

Overfilling the DFT may upset the steam-water balance and cool the water to such an extent that deaeration will be ineffective. Overfilling the DFT also wastes heat and fuel. The excess water, which will have to run down to the condenser, will be cooled. When it reenters the DFT, more steam will be required to reheat it. If an excessive amount of cold water enters the DFT, the temperature drop in the tank will cause a corresponding drop in pressure. As the DFT pressure drops, more auxiliary exhaust steam enters the tank. This reduces the auxiliary exhaust line pressure, which causes the augmenting valve (150-psi line to auxiliary exhaust line) to open and bleed live steam into the DFT.

When an excessive amount of cold water suddenly enters the DFT, it may cause a serious casualty. The large amount of cold water will cool (quench) the upper area of the DFT and condense the steam so fast that pressure is reduced throughout the DFT. This permits the hot condensate in the lower portion of the DFT and feed booster pump to boil or flash into vapor. The booster pump then loses suction until pressure is restored and the condensate stops boiling. With a loss of feed booster pump pressure, the main feed pump suction is reduced or lost entirely. This causes serious damage to the feed pump and loss of feedwater supply to the boiler(s). Some ships have safety devices installed on the main feed pumps to stop them when a partial or total loss of main feed booster pressure occurs.

The mixture of condensate, drains, and makeup feedwater, constituting the inlet water to the DFT, enters through the tubes of the vent condenser. The condensate pump discharge pressure forces the water through the spray valves of the spray head and discharges it in a fine spray throughout the steam-filled top or preheated section of the DFT.

If a spray nozzle sticks open or if a spray nozzle spring is broken, the flow from the nozzle will not be in the form of a spray, and the result will be ineffective deaeration. This condition cannot be discovered except by analysis of the feedwater leaving the DFT or by inspecting the spray nozzles.

Maintenance of a Deaerating Feed Tank

DFT maintenance can usually be limited to scheduled planned maintenance checks. They include, but are not limited to, the following checks:

1. Lift the shell relief and vacuum breaker valves by hand to ensure freedom of movement.
2. Test the DFT remote water level indicators.
3. Test the operation of the air-pilot-operated control valves for makeup and excess feedwater control.
4. Inspect the internal components for presence of oil and foreign matter; clean as necessary.
5. Inspect and clean the DFT check valve.
6. Test DFT spray valves.

If the DFT is not operating satisfactorily, insofar as proper temperature and deaeration is concerned, the failure can usually be traced to one of the following problems:

- You may be using improper sampling and analyzing techniques. Ensure that a representative sampling of the feedwater is being obtained for the dissolved oxygen test.

- Excessive fluctuations in auxiliary exhaust pressure will cause unstable conditions in the DFT. The auxiliary exhaust system augmenting steam valves and dump valves should be maintained in proper condition to automatically control the exhaust pressure under all plant conditions.

- Excessive HP drain pressure can close the internal check valve, thereby starving the

deaerating section of necessary steam required for vigorous scrubbing action and final oxygen removal.

- Faulty operation of the spray valves will critically affect deaeration.

For further information concerning maintenance and repair, consult the applicable chapters of the manufacturer's technical manual.

OIL COOLERS

Oil coolers should be operated as required to maintain the oil (inlet) temperature to the bearings at the designed value. With the bearing orifices properly adjusted and the bearings in proper operating condition, a temperature of 120 °F to 130 °F on the discharge side of the cooler should satisfactorily meet all normal operating conditions.

When the system has more than one cooler, they should be used alternately and for approximately the same number of hours.

Maintenance of Lube-Oil Coolers

With reasonable care, lube-oil coolers on Navy ships will remain in service for several years. When salt water is used as the cooling medium, failure is usually caused by erosion, because of high water velocity, or by corrosion, because of electrolytic action.

All coolers are built in accordance with NAVSEA specifications. These specifications are designed to give adequate cooling with seawater velocities well below that which will cause appreciable erosion.

Reports of failure of this type of equipment are rare in comparison with the number of coolers installed in naval ships. Most cooler failures have occurred to units that are supplied with cooling water from a service main. In these cases, the supply of seawater available to the cooler is limited only by a valve or an orifice in the cooler supply line. Under these conditions, too wide an opening of the valve, too large an orifice, or too high a pressure in the service main will cause excessive velocity through the cooler and consequent failure because of erosion. At the same time the oil temperature is usually not appreciably lower than that obtained with proper seawater flow.

Of the two causes of cooler failure, the more likely one is erosion from high-velocity seawater. To get satisfactory service from these units, use the following precautions:

- Limit the seawater flow to the minimum that is consistent with maintaining the oil temperature within limits specified by NAVSEA or as given in the manufacturer's technical manual.

- When securing a cooler for any extended period, drain the saltwater side and flush with freshwater, when practical. At all other times keep the cooler flooded and flush it periodically with salt water.

- Clean in a manner prescribed by NAVSEA.

All of the above precautions also apply to other heat transfer equipment, such as refrigeration condensers, air compressor intercoolers and aftercoolers, and other coolers that use seawater as a cooling medium.

Cleaning Lube-Oil Coolers

If a lubricating system becomes contaminated with salt water, thoroughly clean the system before it is put back into service. Disassemble and remove all traces of rust, scale, and other foreign matter; otherwise, serious damage will result.

All foreign matter in shell and tube coolers must be removed from the inside of the shell and baffles before reassembly. Remove the material with scrapers and/or wire brushes.

With proper use of lubricating-oil purifiers, filters, and strainers, it will usually be necessary to clean only the saltwater sides of the shell and tube-type coolers. This cleaning should be done with an air lance or water lance, and if necessary, with a round bristle brush. Never use a wire brush for this purpose.

Removed tube bundles can be cleaned, when necessary, by flushing them with hot water. However, do not clean shell and tube-type coolers with chemicals without the specific approval of NAVSEA.

AIR COOLERS

Air coolers are used for closed-circuit cooling of machinery. In this type of cooler, the air is circulated over and over again. Closed-circuit

cooling has the following advantages over open-circuit cooling, in which the atmospheric air is passed through the machine:

- The machine is cleaner and is protected from any harmful gases or moisture that may be present in the outside air.

- There is a low fire risk since not enough oxygen is in the enclosed air to sustain combustion.

- The cooling of the machine is independent of outside air.

Maintenance of Air Coolers

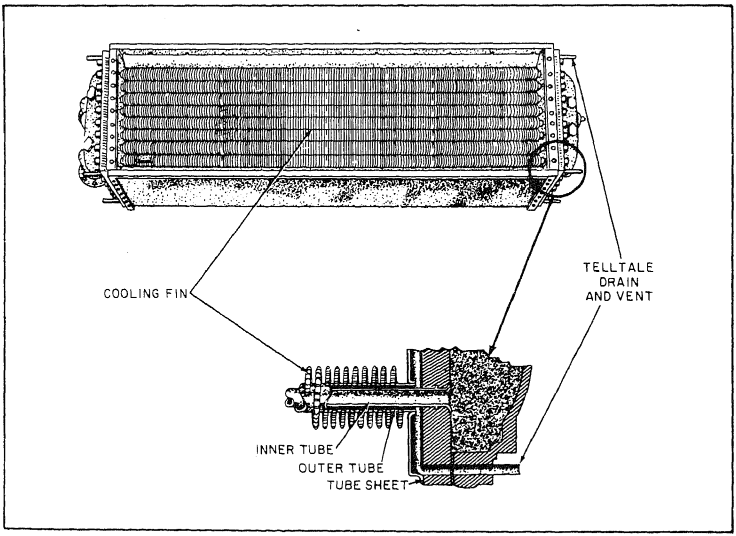
The air cooler (fig. 5-6) is a double-tube type of cooler. The double-tube construction makes it easier to find leaks in the water tubes before serious tube failure occurs.

Each double tube consists of a water-carrying tube surrounded by a close-fitting outer tube. Axial grooves in the inside surface of the outer tube extend the full length of the cooler. The grooves in the tubes all open into telltale chambers at each end of the cooler. If a leak occurs in one of the main water-carrying tubes, the leaking water runs into the grooves in the surrounding tube, and from there it runs into one of the telltale chambers. This arrangement prevents water leakage into the air ducts of the machine. You know you have a leak when you see a discharge from the open ends of the telltale drain tubes.

Proper operation and maintenance is necessary for continuous satisfactory service from the air coolers. Inspections and preventive maintenance help you locate and prevent trouble before serious damage results.

Cleaning of Air Coolers

The air cooler must be cleaned whenever foreign matter interferes with the flow of air across the tubes, whenever water deposits impair the flow of water through the tubes, or whenever such accumulations either inside or



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outside the tubes, prevent proper heat transfer. Clean the cooler at least every 6 months using the following procedures:

CAUTION

Never use abrasive tools that might scratch or mar the tube surface. Any local scratch in the thin film of corrosion products on the surface of the tubes is likely to form the nucleus of a pit of corrosion, that may widen, deepen, and cause tube failure.

1. Close valves in water lines to and from the air cooler. Drain water from the cooler.
2. Disconnect water, vent, drain, and telltale connections.
3. Clean the water passages as follows:
   a. For ordinary cleaning, push an air lance through each tube; then wash the tube sheets and remove all foreign matter from the water chests.
   b. In case of more severe fouling, push a water lance instead of an air lance through each tube.
   c. In cases of extreme fouling of tubes resulting from oil or grounding of a vessel, run a rotating bristle brush through each tube. You may also drive soft rubber plugs through the tubes with an air or water gun. Follow the brush with a water lance.
4. Clean the outside of the tubes with compressed air.
5. Reassemble, using new gaskets.

AIR EJECTORS

In most ships, the first and second stages of the air ejectors and their condensers have been combined into one complete assembly. In many ships, the gland exhaust condenser has been incorporated within the shell of the aftercondenser. The shell is rectangular and is divided by a longitudinal plate into the intercondenser and the aftercondenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the aftercondenser section.

Two sets of nozzles and diffusers are furnished for each stage of the air ejectors to provide continuous operation. Only one set is necessary for operation of the plant; the other set is kept ready for use in case of damage or unsatisfactory operation of the set in use. The two sets can be used simultaneously when excessive air leakage into the condenser calls for additional pumping capacity.

An interstage valve is provided between the discharge of each first-stage ejector and the intercondenser. This ensures that the pressure built up by the first-stage jet, in operation, will not be lost back to the condenser through the idle first stage. For a similar reason, a cutout valve is located between each second-stage suction chamber and the intercondenser. By means of diaphragm plates in the inlet and outlet heads, the cooling water (condensate) is forced to make several passes through the unit before being discharged.

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster). This fan provides a positive discharge through piping to the atmosphere above decks. This is necessary to avoid filling the engine room with steam should the air ejector cooling water supply fail. Such a failure allows the steam to pass through the intercondenser and aftercondenser without being condensed.

OPERATION OF AIR EJECTORS

With each air ejector assembly installed, the manufacturer furnishes technical manuals on operation and maintenance. General information on starting, shifting, and securing air ejectors is given in each ship's engineering operational sequencing system (EOSS). Some additional operating procedures are listed below:

- Before starting a steam air ejector, drain the steam line of all moisture. Moisture in the steam line will cut the nozzles, and slugs of water will cause unstable operation.

- Before cutting steam into the air ejectors, make sure that enough cooling water is flowing through the condenser and the condenser has been properly vented.

- Keep the loop seal line airtight; an air leak may cause all water to drain out of the seal.

- If operating both sets of air ejectors is necessary to maintain proper condenser vacuum, you probably have an air leak. It is better to eliminate the air leak than to operate two sets of air ejectors.

Unstable operation of an air ejector may be caused by any of the following: The steam

pressure may be lower than the designed amount. The steam temperature and quality may be different than design condition. There may be scale on the nozzle surface. The position of the steam nozzle may not be right in relation to the diffuser. The condenser drains may not be right in relation to the diffuser, or the condenser drains may be stopped up.

Low pressure problems are generally caused by improper functioning or improper adjustment of the steam-reducing valve supplying motive steam to the air ejector assembly. Dry steam at full operating pressure must be supplied to the air ejector nozzles.

Erosion or fouling of air ejector nozzles is evidence that wet steam is being admitted to the unit. Faulty nozzles make it impossible to operate the ejector under high vacuum. In some instances, the nozzles may be clogged with grease or some other deposit, which will decrease the jet efficiency.

MAINTENANCE OF AIR EJECTORS

In general, air ejector nozzles may be cleaned with reamers. Use the proper size reamer for each size of nozzle, to avoid damage to the nozzle. If you must remove the nozzle for cleaning or replacement, the internal surfaces must not be damaged. Dents or deformations of the downstream end of the nozzle and rough or scratchy surfaces in the throat or diffuser passages will cause improper operation of the unit. Remove foreign deposits from the internal surface of the nozzle or diffuser with a nozzle reamer, soft copper wire, or piece of wood.

Before you disassemble or reassemble nozzles or diffusers, refer to the manufacturer's technical manual. If replacement of a nozzle or diffuser is required, use gaskets of proper thickness for reassembly. The nozzle and the difffuser tube must be concentric and in proper alignment, and the correct distance must be maintained between the ends of the nozzle and the diffuser.

Steam strainers, nozzles, or diffusers of an air ejector assembly may be cleaned or replaced while the rest of the unit is in operation. The unit that is to be opened must be isolated from the rest of the assembly to avoid burns on personnel. You can do this by closing the steam supply valve and the interstage valves of this unit.

Flooded Condenser

Improper drainage or leaking condenser tubes will cause flooding of the intercondensers and aftercondensers. If flooding occurs, the effective condensing surface is decreased, and there is a loss of vacuum. Flooding may also cause condensate to be drawn into the second-stage element, which will cause erratic operation of the unit.

If flooding is suspected, clear out drain lines and do a hydrostatic test on the unit to check for leaks at tube joints and tube walls. Tubes rarely need replacing, as most installations use condensate as a cooling medium.

If tubes do leak, the packed ends can be repacked by use of copper-asbestos packing rings supplied by the manufacturer. You can remove old packing rings and install new ones in the same manner as described in this chapter for packing of main condenser tubes. The exception is that copper-asbestos rings should be set up with several very light hammer blows on the caulking tool. Copper does not flow into the threads of the packing box as readily as does the lead packing used in main condensers.

To make an emergency repair of a tube, plug both ends. Should retubing or other major repairs be necessary, conduct a hydrostatic test on all parts of the assembly to the test pressure specified by the manufacturer. Determine that all internal parts of the assembly are in proper working order before the new tubes are installed. Make a positive test to establish the tightness of the gaskets between the intercondensers and aftercondensers both before and after installing new tubes.

Maintaining the Loop Seal

An air leak in the U-shaped loop seal line (fig. 5-7) provided for draining the intercondenser makes it impossible to maintain a seal between the intercondenser and the main condenser. Water from the intercondenser passes down through the small 1-inch pipe, then through the short loop, and up through the internal pipe. The larger pipe surrounding the internal pipe is 3 inches in diameter and is connected to the main condenser. Water overflowing the internal pipe fills the external pipe and the larger loop.

If no vacuum existed in either condenser and if water from the intercondenser entered the internal pipe, it would maintain the same height in each leg.

When a vacuum is formed in both condensers, the difference between the vacuum maintained in the main condenser and that maintained in the intercondenser will be about 3 inches. The vacuum in the main condenser will be about 29 inches and that in the intercondenser about 26 inches.

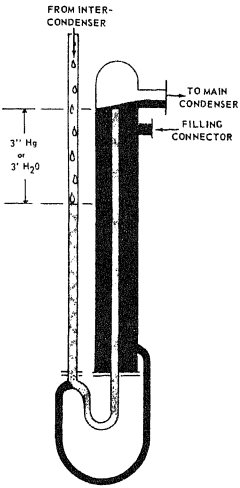

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Figure 5-7.—Loop seal.

If you express vacuum in terms of absolute pressure, a pressure of 1/2-psi will be acting down on the internal and external pipes, and a pressure of 2 psi will work down against the water level in the primary 1-inch pipe. This means that the pressure of 2 psi from the primary pipe will push water through the pipe and cause it to overflow from the external pipe into the main condenser.

When the water level in the primary leg is approximately 3 feet below that of the secondary leg, the additional weight of the water present in the secondary leg will provide the extra 1 1/2 psi necessary to counteract the 2-psi absolute pressure against the primary leg. Thus, a static condition will be obtained. If water from the intercondenser is added to the primary leg, the level on that side will rise. The additional weight of the water will cause water to be pushed into the main condenser from the secondary leg. This will restore the loop to its original static condition.

To drain water from the intercondenser to the main condenser, add water to one side of the loop and remove it from the other side. A solid body of water is maintained in the base of the loop and prevents air from passing through, which would cause an equalization of vacuum.

The purpose of the filling connection is to allow condensate to be pumped from the condensate pump discharge line to the loop seal so that the loop may be filled before placing it in operation. A cutout valve is installed in the line from the loop seal to the main condenser.

If the vacuum gauges on both the main condensers and intercondensers show the same reading, this indicates that the seal is broken. Opening the filling valve will correct this condition if it is caused by a sudden surge in vacuum or a violent roll of the ship. If the condition is caused by an air leak, the leak will have to be corrected before the loop will remain properly sealed.

CHAPTER 6

PUMPS

As an MM1 or MMC, you will be responsible for the operation and maintenance of pumps and pump governors in the engine room and other machinery spaces. This chapter covers the inspection and repair of reciprocating and centrifugal pumps and the operation and repair of pressure-regulating and speed-limiting governors.

Before studying this chapter, you may find it helpful to review chapter 5 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-F, and *Naval Ships' Technical Manual*, chapter 503.

RECIPROCATING PUMPS

Reciprocating pumps were once widely used on board Navy ships for a variety of services. However, centrifugal and rotary pumps are now far more common in modern ships of all classes. Reciprocating pumps are generally restricted to use as emergency feed pumps, fuel-oil pumps, and lube-oil tank stripping pumps. On some of the older ships, fuel-oil-transfer, bilge, and ballast pumps may be of the reciprocating type. A reciprocating pump may be either a high- or low-pressure or single- or double-acting pump, depending on how it is used. For instance, an emergency feed pump is normally a high-pressure pump, which means the steam piston is larger than the water piston, and is a double-acting pump, which means it discharges on both strokes. This type of pump is used when your major concern is getting water into the boiler. On the other hand, a bilge and stripping pump has a higher volume output at a lower pressure. Many emergency feed pumps can use LP air; however, the air and steam should never be interfaced.

OPERATION OF RECIPROCATING PUMPS

You will sometimes have operating problems with reciprocating pumps. Some of the most common causes of trouble and their remedies are covered in the following material.

Failure to Start

There may be times, after you have lined up the pump and cracked open the throttle valve, that the pump will not start. You may repeat the starting procedure and determine that everything seems to be all right, but still the pump will not start. At this point, proceed as follows: Secure the pump. Check the suction, discharge, and auxiliary steam exhaust lines. Look for a closed valve or for a valve disk that has come off its stem. If no valves are closed, the water piston or the steam piston may be frozen, especially if the pump has been idle for some time. This may be determined by jacking the pump with a bar.

CAUTION

Never attempt to jack a reciprocating pump unless you are certain that the throttle valve and the exhaust valve are closed tightly and the steam-cylinder and steam-chest drains are wide open.

If there is no excessive friction, disconnect the auxiliary valve stem from the operating gear. Do not disturb the adjustment of the tappet collars. Open the exhaust, suction, and discharge valves and then crack the throttle. Work the auxiliary piston valve by hand (it should slide freely). Should the pump still not start, secure steam and water end valves. Remove the steam valve chest to determine whether the main piston valve has overridden or stuck. An erratic operating pump may indicate excessive dirt or contamination in the pilot valve. This may cause the valve to be jammed in the valve body.

If the pump still cannot be started, you may need to overhaul the working parts of the steam end. Excessive force (such as using a hammer) on the pilot valve drive rod will only result in further operating difficulties to the pump.

Failure to Take Suction

When a reciprocating pump fails to take suction, the operation will be jerky. To correct this, proceed as follows: See that all stop and check valves in the suction line are open. Ensure that the suction line is free of all obstructions. If a reciprocating feed pump should become vapor bound, shift suction to a standby feed tank. Open the vent valves in the valve chest cover and the discharge line to help cool the pump. Shift to the standby feed pump, if available, until the vapor-bound pump cools.

Pumps with a suction lift may need priming before they will take suction. You can usually prime seawater pumps by opening the sea suction for a short interval.

If the lack of suction is caused by defective valves in the water end, the defects will have to be corrected before the pump will operate satisfactorily.

Loss of Discharge Pressure

There are several reasons for a reciprocating pump to lose discharge pressure; some of the major reasons are listed here:

- Low steam pressure. Loss of steam pressure will cause the pump to slow down and lose pump capacity and discharge pressure.

- High back pressure. If the auxiliary exhaust pressure becomes abnormally high, the pump will slow down, and the discharge pressure will drop.

- Worn piston rings. Leakage of steam by worn piston rings will cause the pump to operate erratically or stop. When worn rings are suspected, disassemble the steam end and take the ring and piston measurements. If measurements are below the designed allowances, renew the rings.

- Defective valves. If a pump is operating normally and suddenly loses discharge pressure, look first for a defective valve that will cause a large loss in efficiency. If a pump races without increasing the discharge pressure, the cause is probably defective valves or air leaking into the suction line.

- Worn plunger packing. The packing on the water end plunger will wear, over a period of time; and the maximum discharge pressure from the pump will decrease accordingly. The only remedy is to renew the packing. When packing a pump with tucks, flax, or other soft packing, soak the packing in hot water for 12 hours before fitting and installing. Follow the procedures in the manufacturer's technical manual.

When you are trying to locate and correct troubles in a reciprocating pump, previous experience with a particular pump is always helpful. First, check all accessible parts. If you cannot find the trouble without disassembling the pump, check the water end before you remove any parts from the steam end. Most pump troubles are caused by fouled water cylinders, worn valves, or conditions in the pipe connections external to the pump.

MAINTENANCE OF RECIPROCATING PUMPS

Repairs must be done in accordance with the manufacturer's technical manual. The system ensures that every part of the pump that requires attention or contributes to poor performance is put into proper condition. When you do a partial overhaul, check NOT DONE on the repair data list for items that are not repaired. This will show that every part was inspected and that corrective maintenance was done where necessary. Upon completion of a pump overhaul, keep the repair data list as a permanent record of all measurements taken and all work done.

When you disassemble a pump for repair or inspection, be sure you have all applicable blueprints, the manufacturer's technical manual, and available dimensional data. Take micrometer measurements of the steam and water cylinders and the steam valve chest. Take these measurements on the fore-and-aft and athwartship diameters at the top, middle, and bottom. Record the results with a sketch showing measurements taken.

Improper alignment is a frequent source of trouble with pumps. Pumps with mountings secured to a bulkhead become misaligned more often than those with independent bases. A pump may have been properly aligned in the shop and then pulled out of line when bolted to the bulkhead mounting. After the pump mounting was secured, the ship may have changed shape enough to warp the bulkhead and cause misalignment.

The operation of an improperly aligned pump usually scores the rods and cylinders and breaks the followers. Test the alignment of pumps occasionally by removing the piston and plunger and running a line through the steam and water cylinders. Make this a routine test within the first year after a ship is commissioned and for a pump that is scoring rods or cylinders or breaking followers.

Before you run a line through the cylinder or make any adjustments, line up the foundation and determine the center line. The center line must divide each cylinder equally (fig. 6-1). Fasten one end of the line on a finger piece secured to the bottom of the water cylinder and the other on a temporary beam rigged above the steam cylinder. Then center the line at the bottom and top of the water cylinder so that it becomes the axis of this cylinder, as shown in figure 6-1. You can then move the steam cylinder about and center it on the line without disturbing the centering of the line on the water cylinder.

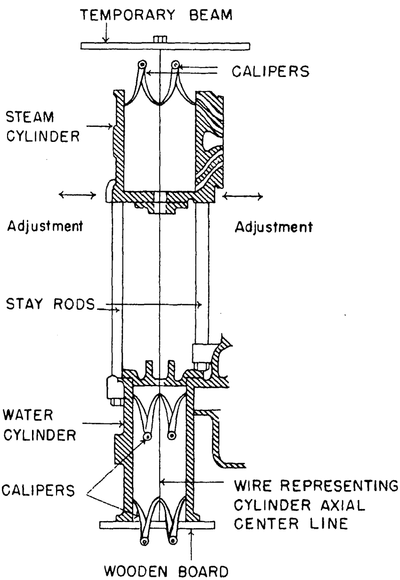

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Figure 6-1.—Centering a line through two cylinders.

To make a rough check of the alignment of a pump, pull the steam and liquid end rod packing and check the clearances between the piston rods and the cylinder throat bushings. Make this check with the pistons in each of three positions—top, center, and bottom of the stroke. If clearance is not uniform but the throat bushings are not worn out of round, realign the pump as soon as possible.

In some cases, when steam cylinder foundation pad bolts are slacked off, the cylinder pads pull away from the foundation as much as one-half inch. This indicates settling of foundations and bulkheads. Correct this by fitting shims between the foundation and the pump.

Piping stress is a frequent cause of misalignment. The piping should line up naturally with the pump connections and should not be forced into position. Always allow for expansion in steam and exhaust lines. Support all piping independently of the pump. Improperly installed piping puts a strain on the pump inlet and outlet connections and may force it out of alignment. Take special care to avoid vapor pockets when you install suction piping.

CENTRIFUGAL PUMPS

Centrifugal pumps are widely used on board ship to pump water and other nonviscous liquids. They have several advantages over reciprocating pumps: They are simpler, more compact, lighter, and easily adapted to a high-speed prime mover.

Centrifugal pumps also have disadvantages: They have poor suction lift characteristics, and they are sensitive to variations in head and speed.

Centrifugal pumps are usually designed for specific operating conditions and will not give satisfactory results when their rated operating conditions are altered. Before installing any centrifugal pump, be sure you understand the principle of operation and the design limitations of the specific pump.

OPERATION OF CENTRIFUGAL PUMPS

The details of operation for a centrifugal pump may vary from pump to pump. Pumps may look alike, but this does not necessarily mean that they are operated in the same manner. Post detailed instructions for operating a specific pump near the pump. Before operating the pump read the instructions carefully. Follow the step-by-step instructions in the engineering operational sequencing system (EOSS).

Many pump casualties affect the speed of the ship. Those caused by improper operation could be prevented by attentive watch standing. Always follow the engineering operating procedures and manufacturer's instructions for starting, operating, and securing pumps. This will help prevent casualties.

Starting a Centrifugal Pump

The instructions contained in this chapter for the operation of pumps are general. All pumps cannot be covered because of the many makes and types of pumps installed aboard naval ships. Manufacturers' technical manuals are furnished with all but the simplest of pumps. Those manuals contain detailed instructions on specific pumps. Study them carefully before you operate the pumps.

Before starting a centrifugal pump for the first time or after an overhaul, you should check several items. Carefully check the coupling alignment. Flexible couplings will take care of only very slight misalignment, usually about 0.002 to 0.004 inch. The exact figure can be found in the manufacturer's instructions. Excessive misalignment will cause the coupling to fail. This may cause failure of the pump shaft or bearings.

If the pump is motor driven, check the rotation of the unit. Most pumps have an arrow on the pump casing that indicates the proper direction of rotation.

Check all piping that pertains to the pump. During overhaul, most valves in the piping will have been closed. The lube-oil system and the suction, discharge, vent, recirculating, and bypass valves must be lined up properly. Be sure an adequate supply of water is available for the lube-oil cooler; and check the inlet, outlet, and root valves.

The following checks and actions are not necessarily listed in any proper order, and all items do not apply to all steam-driven pumps. Operate the pump in accordance with the ship's EOSS. Use these checks and actions to start a steam-driven centrifugal pump.

1. Check the level of oil in the sump tank or bearing housing. Fill any oil cups or reservoirs. If the pump is lubricated by a detached pump, open and adjust all valves in the discharge and suction lines.
2. Rotate the handle of the lube-oil filter. Lubricate the linkage on the speed-limiting governor.
3. Open the suction valve, the vent, and the recirculating valves. Open any valves in gland water seal lines. (The discharge valve should be closed when you start centrifugal pumps.)
4. Open the steam and exhaust root valves.
5. Check the suction pressure (if applicable).
6. Open all steam drains.
7. Open the turbine exhaust valve.
8. Open the bypass around the governor (if fitted).
9. Crack the turbine throttle valve.
10. Increase the steam-chest pressure until the pump is turning fast enough to ensure adequate lube-oil pressure.
11. Check the packing glands for proper leak-off.
12. When the pump vent blows a solid stream of water, close the vent.
13. Close the pump governor bypass and test the constant-pressure governor.
14. When lube-oil temperature reaches 90 °F, open the valve to allow cooling water to flow into the lube-oil cooler.
15. When ordered to put the pump (not fitted with a pressure governor) on the line, increase the pump discharge to the required amount by opening the throttle valve to the necessary speed. If the pump is fitted with a constant-pressure governor, set the governor to give the required discharge pressure.
16. When the pump is delivering the required discharge pressure, open the pump discharge valve.

Operating a Centrifugal Pump

When a pump has been started, do not leave it unattended. Have an experienced person on hand to check for abnormal operation. Make frequent checks on the temperature of the lube oil leaving the cooler and each bearing. The suction and discharge pressures may become too high or too low. Packing glands may overheat and burn out.

The principal troubles that may occur with centrifugal pumps are as follows:

- Low discharge pressure. There are several reasons why a pump will not discharge at maximum capacity or pressure. The pump may be improperly primed, thus the proper quantity of liquid does not reach the pump casing. The speed of the pump may be too slow. On a turbine-driven pump, the speed-limiting governor may be set too low, or the constant-pressure governor may need

adjusting. The pump may have mechanical defects such as worn wearing rings, worn bearings, a bent shaft, or a damaged impeller.

- Loss of suction. If a pump has been operating satisfactorily and loses suction, air may be entering the suction line or packing glands. The suction strainer may have become clogged, or dirt or other foreign matter may have entered the impeller opening. In a main feed pump, the main feed booster pump may not be operating at its normal discharge pressure.

- Excessive vibration. In a pump, excessive vibration may be caused by one of the following: misalignment of the unit, a sprung foundation, worn impeller rings, worn bearings, a bent shaft, an improperly balanced impeller, or a broken impeller.

When putting a main feed pump on the line, make sure the main feed booster pump is maintaining the required pressure. Boiler feedwater is discharged under pressure from the main feed booster pump to the suction side of the main feed pump. This in turn discharges the feedwater through the feed line to the boiler at a high pressure.

There are two sets of wearing rings in each stage. These wearing rings have a minimum of clearance, as do the rings in a main feed booster pump. However, the rotation of a main feed pump can be five times as great as that of a main feed booster pump. Therefore, the possibility of seizure of the main feed pump wearing rings is much greater.

Water entering the suction of the main feed pump has its pressure reduced while passing through the entrance ports. Since this water is at a temperature of about 240 °F, this reduction in pressure might easily cause the water to flash into steam. If this occurs, the pump will become vapor bound. The water cannot then flow through the pump and remove heat from the pump casing. A vapor-bound feed pump will require about 15 seconds to overheat, causing the wearing rings to seize.

The main feed booster pump discharge should be maintained as near the designed value as possible. For an installation designed to operate at 50 psi of booster pressure, the main feed pump should not be turned over when there is less than 40 psi of booster pressure.

When main feed pumps are running, ensure the oil temperature and pressure at the bearings are in accordance with the manufacturer's operating instructions. If a detached lube-oil pump is provided, it will automatically cut in if the lube-oil pressure falls below a predetermined amount. If low lube-oil pressure develops after the detached lube-oil pump starts, shift to the standby unit. Secure the faulty unit and determine and correct the cause of low lube-oil pressure. On installations without a detached lube-oil pump, if low lube-oil pressure occurs, shift immediately to the standby unit. Do not operate the faulty pump until the proper lube-oil pressure has been restored.

There is a common tendency to tighten packing glands too tightly. This causes the packing to burn and leads to scoring of the shaft sleeves. The packing glands should be adjusted so that a small amount of water is leaking out of the stuffing boxes. This water lubricates and cools the packing and packing gland. The packing gland should always be parallel to the face of the stuffing box and not cocked at an angle. If a stuffing box leaks excessively and it becomes necessary to tighten the gland, take up evenly on the gland bolts by a slight turn. Wait a reasonable time. Then, if the leakage is still excessive, tighten the gland bolts by another slight turn. Continue this procedure until there is only a trickle of water from the stuffing box.

When a main feed pump is running, do not change from hot to cold suction or vice versa, unless there is an extreme emergency. Make periodic checks for vibration of the pump and driving unit. If vibration becomes excessive, stop the pump and investigate.

When a main circulating pump is used to pump the engine-room bilges, start the pump in the same way you would for main condenser circulating service. Then gradually close the main injection valve and open the bilge suction valve. When the pump is operating on a high-suction lift, as when pumping bilges, reduce the speed to about two-thirds of rated speed. Even then, the pump will be noisy. This cannot be avoided but can be minimized by slowing the pump.

Securing a Centrifugal Pump

To secure a steam-driven centrifugal pump, proceed as follows:

> NOTE
>
> These procedures are not necessarily listed in any proper order and may or may not apply to all centrifugal pumps. Secure the pumps in accordance with the ship's EOSS.

- Close the pump discharge valve.
- Close the throttle valve.
- Close the exhaust valve.
- Close the suction valve.
- Close the vent, recirculating, and gland-sealing valves. (On some units, recirculating and vent valves are locked open.)
- Open the turbine casing drain.
- Close the stem and exhaust root valves.
- Close the turbine casing drain after the turbine is completely drained.

MAINTENANCE OF CENTRIFUGAL PUMPS

This chapter contains some of the information you must have to give proper care and maintenance to centrifugal pumps. Before you try to repair any pump, study the manufacturer's technical manual and the maintenance records carefully.

Bearing Maintenance

Pump bearings must receive approximately the same tests, inspections, and maintenance as bearings installed in other units of naval machinery. Pump bearings must be supplied with an adequate amount of oil at the right temperature and of the viscosity designated for that particular pump. The manufacturer's technical manual contains information on lubrication of each pump.

THRUST BEARINGS should be examined in accordance with PMS. Check the condition of the bearing and the position of the rotor. When checking the rotor position, allow for expansion of the shaft from a cold to a hot condition. There are many types of thrust bearings installed in pumps. Study the manufacturer's technical manual before you disassemble any thrust bearing.

JOURNAL BEARINGS should be systematically inspected. Check the condition of the journal and the bearing surface and correct any deficiencies. Take lead readings and maintain bearing clearances as shown in the manufacturer's plans. If the manufacturer's technical manual is not available, follow the instructions in chapter 244 of *Naval Ships' Technical Manual.*

WATER-LUBRICATED BEARINGS are installed in main condensate pumps and main condenser circulating pumps. In main condensate pumps, the bearing is located in the casing, between the first-stage and second-stage suction compartments, where it also serves as an interstage seal. Vertical movement of the bearing is prevented by shoulders in the casing; and a stop pin prevents angular movement. During normal operation of the pump, the bearing is lubricated by a constant flow of water through the bearing. This flow is maintained as a result of the pressure differential between the two suction compartments.

In main condenser circulating pumps (fig. 6-2), the water-lubricated bearing is located immediately above the propeller and is designed for a radial load only. The bearing is held in place by shoulders in the casing and is lubricated by the flow of water through the pump.

A number of materials have been used for water-lubricated bearings, such as leaded bronze, graphited bronze, lignum vitae, laminated phenolic material grade FBM (fabric-based Bakelite or Micarta), and barium. Most water-lubricated bearings are now made of rubber or phenolic material.

Check the condition of water-lubricated bearings frequently. Excessive wear causes shaft misalignment and possible bearing wear or shaft breakage.

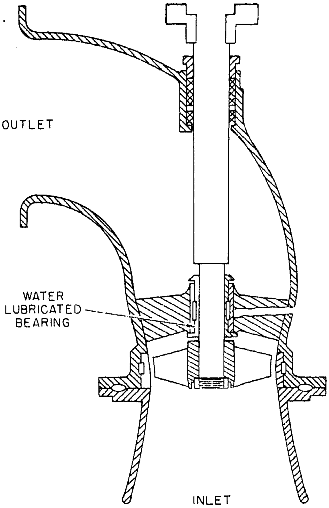

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Figure 6-2.—Main condenser circulating pump, showing internal water-lubricated bearing.

BALL and ROLLER BEARINGS are used in many shipboard pumps, especially in small pumps and in main condensate, main feed booster, and lube-oil service pumps. These bearings must be handled as carefully as any other piece of precision equipment. The following precautions will aid in proper bearing maintenance:

- Do not remove the bearing from its container until you are ready to install it.

- Be certain that the journal, housing, or any other mating part is of the correct dimensions.

- Avoid damage during handling; do not drop the bearing; keep dirt and moisture away from the bearing, shaft, and housing.

- Use proper tools to remove the old bearing and install the new one.

- Use the correct lubricant and the proper amount. After assembly, rotate the journal by hand to ensure there is no undue friction.

In rolling contact bearings, the journal is supported by the races and rolling elements rather than the oil film. However, lubrication still plays an important part in the operation because it dissipates heat and prevents corrosion. The oil film also helps keep foreign matter out of the bearing. Use enough grease or oil to provide a protective film over the bearing parts. Too much lubricant will churn, and the bearing will overheat.

When a roller or ball bearing fails in service, it must be renewed, because it cannot be repaired. The replacement bearing must be carefully installed if it is to give satisfactory service.

Replacing Pump Rotors

Pumps, like all machinery, in time, will need overhauling. Much of the work on pumps involves removing the rotor from the casing. To renew wearing rings, bearings, sleeves, or impellers, you must remove the casing and lift out the rotor.

Use the following procedures to disassemble a MAIN FEED PUMP:

1. Wire shut and attach a danger tag to all suction, discharge, vent, and recirculating valves. Drain water from the casing.
2. Remove all suction, discharge, vent, and recirculating lines that will interfere with lifting the casing and rotor.
3. Remove the bearing caps and the bearings (journal and thrust).
4. Disconnect the coupling between the turbine and pump.
5. Remove the packing glands and the packing.
6. Remove the pump casing horizontal joint bolts.
7. Break the horizontal casing joint by tightening the jack screws.
8. Attach the lifting gear to the upper half of the casing (eyebolts are provided for this purpose).
9. Lift the upper half of the casing until it is clear of the rotor. Change the lifting gear and swing the upper casing half clear of the pump.
10. Attach cables around the shaft at both ends, making certain that you do not lift on a journal surface. Lift the rotor out of the lower half of the casing.
11. The rotor can then be moved to a location where it can be disassembled. To have access to all rotor parts, place the rotor on a workbench or two wooden sawhorses.

Remove all rotor parts in the sequence and in the manner recommended by the manufacturer.

It may be necessary to heat the impellers to remove them. If so, warm the impeller evenly all around while keeping the shaft as cool as possible.

When the rotor parts are disassembled, check the shaft carefully. Check the journal surfaces for burrs or nicks. If a lathe is available, the shaft can be swung in the lathe. You can then use a dial indicator to determine whether the shaft is bent or the journals are out of round. The journal surfaces can be measured with an outside micrometer to determine whether there is wear. If the journals are worn or out of round, they can be built up and machined to the designed diameter at a repair activity. If the wearing rings are to be renewed, they will have to be fitted either in the ship's machine shop or at a repair activity.

Before you reassemble the rotor, make sure that all parts are clean and free of burrs (especially the faces of the impeller and the sleeves).

The following clearances should be within the limits indicated in the manufacturer's technical manual: the oil clearances of the journal and thrust bearings, the running clearance of the wearing rings, the clearance between the impeller and diaphragm bushing, and the clearance between the shaft sleeve and stuffing-box bushing.

Before lowering the rotor, roll in the lower half of the journal bearings. Clean all dirt and foreign matter from the lower half of the casing. Use a new parting flange gasket to avoid leaks; internal leaks will lower the efficiency and maximum capacity of the pump.

Attach the lifting gear and lower the rotor into the casing. Make sure that all stationary rotor parts—diaphragms, casing rings, and stuffing-box bushings—will enter their respective fits in the casing without binding. If you need to use force to get the rotor parts into the casing, remove the rotor and check all parts for dirt and burrs.

When the rotor is in place, lower the upper half of the casing. Ensure that the casing fits over the rotor easily. If it does not, remove the upper casing half and examine it for dirt and burrs. When the upper and lower casing halves contact each other properly, insert the casing dowels. Next, tighten the parting flange nuts; tighten them evenly several times. Assemble the thrust bearing; then place the upper half of the bearings in position and bolt the two halves of each together. Adjust the flingers; they should be close to the face of the bearings but MUST not rub. Tighten the flinger setscrews and close up the bearings by placing the caps over them and tightening the bolts. Take a reading on the thrust bearing clearance.

The pump shaft and turbine shaft MUST be in correct alignment. For information on pump alignment, refer to the manufacturer's technical manual or *Naval Ships' Technical Manual*, chapter 503.

All water lines MUST be in place and tightened before you attempt to align the unit. Otherwise, tightening the lines may cause misalignment of the unit. Pack the stuffing boxes with the proper packing; then the unit is ready to be tested.

Rotate the pump several times by hand before you cut steam into the driving unit. Ensure there is no undue binding or friction.

The procedure for replacing a MAIN CONDENSATE PUMP ROTOR or a MAIN FEED BOOSTER PUMP ROTOR is similar to the procedure described above. These pumps are usually mounted vertically. The rotor can be disassembled without disturbing the driving unit. The procedure is as follows:

1. Obtain the manufacturer's technical manual and blueprints. Study the construction details and procedures for assembly and disassembly. Note the manufacturer's data on wearing ring clearances, bearing clearances, and other necessary dimensions. Check the maintenance records; alterations may have been made.
2. Remove the new rotor from its storage place. Clean and inspect the new rotor; take all necessary measurements.
3. Assemble all necessary lifting gear and tools, including special tools.
4. Remove the nuts at the parting flange and remove the casing half. Take off the bearing cap, unbolt the bearing housing, disconnect the coupling, and lift out the old rotor.
5. Inspect the interior of the casing. Clean all flanges and make new gaskets. Use new gaskets on all flanges. Any leakage through a main condensate pump flange will cause a loss of vacuum in the main condenser.
6. After the cleaning and inspecting are done, lower the new rotor into place.
7. Place the casing in position and tighten the parting flange nuts. If the casing binds or does not fit properly, remove the casing and correct the trouble.

8. When the casing has been secured in place, rotate the rotor by hand to ensure there is no binding or undue friction.

9. Reassemble the bearing housing and connect the coupling. If the pump still turns freely, the unit is ready to be tested by steam (or motor). If all conditions are satisfactory, bring the pump up to operating speed and pressure. When the pump is used for the first time, keep it under close observation for several hours. Do not consider it ready for unlimited operation until it has carried the required load with the ship underway.

Prepare a work request for the necessary repairs to the defective rotor. Write up all necessary details, including balancing. Take the rotor to the appropriate repair activity. All pump and driving unit rotating parts are balanced dynamically for all speeds from at rest to 125 percent of rated speed. This is usually done on balancing machines generally available on tenders and repair ships and at all naval shipyards.

Pump rotors may be overhauled on board ships with adequate shop facilities. Take the rotor to the machine shop and dismantle it. Take the parts off the shaft in the sequence recommended by the manufacturer. When the parts have been removed, check the shaft in the same manner described in this chapter for shafts of main feed pump rotors.

If the shaft is not bent or out of round, reinstall the parts on the shaft, using new parts as needed. The best practice is to heat the bearing in an oil bath to about 200°F (but not exceeding this temperature). Slip it over the journal and position it by means of the locknut. The locknut can be tightened as the bearing cools.

Give wearing rings the clearance recommended by the manufacturer. When the rotor is reassembled, stow it properly so that it will be ready for use when needed.

Lubricating Systems

Lack of lubrication or improper lubrication is a major cause of pump failure. Before a pump is started, check the level of oil in the sump not only for the amount of oil, but also for the quality of oil it contains. If water is found in the oil sump, check for leakage from turbine glands, a leaky oil cooler, or any other possible source of water contamination. Check the oil filters or strainers frequently. In those with edge filtration (such as in the Cuno type of filter), sediment will collect in the bottom of the filter. Clean it out frequently. Check the housings of grease-lubricated bearings occasionally to ensure they are free of water, dirt, and other foreign matter. If water is found in the bearing housing, trace it to its source. The frequency with which grease is added to a bearing must be determined by the type of service and the effectiveness of the grease seals.

When starting a pump, check the oil pressure and the flow of oil to all bearings. Make sure that the lube-oil pump is discharging at the designed pressure. Ensure that cooling water is flowing through the oil cooler and that all air is vented from the cooler. It may be necessary to vent the lube-oil system. To do this, open the vent on the highest point in the lube-oil system and close the vent when oil appears.

When water or other foreign matter is found in a lube-oil system, do not operate the unit until the system has been drained, cleaned, and filled with the proper quantity and quality of oil.

ROTARY PUMP ROTORS

Generally, it is more difficult to replace main lube-oil service pump rotors than rotors in other types of pumps. The driving unit must be removed before the liquid end can be disassembled. With the drive unit removed, the pump rotor and rotor housing can be disassembled without removing the mountings or the main lube-oil connections.

Under normal operating conditions, the rotors are completely covered with oil, which cuts rotor wear to a minimum. Therefore, the rotors may give years of satisfactory service without repairs. In some instances, rotor failure has been caused by normal wear; air trapped in the casing; or dirt, wood, or metal objects in the casing. To replace a defective rotor, proceed as follows:

On a turbine-driven unit, remove the drive unit by breaking the steam and exhaust lines. Disconnect the coupling and remove the bolts that secure the spacing frame to the pump casing. Attach the lifting gear and lift the drive unit off intact.

To disassemble the liquid end (fig. 6-3), first remove the lower coupling half, the packing gland, and the upper casing head. The rotors will then be exposed and can be withdrawn. As the rotors are lifted out of their housings, the idlers must be supported; the pump is constructed in such a manner that only the housings hold the rotors in mesh. With the rotors removed, the housings are accessible. The housings fit snugly in the bore of the casing and are separated by a spacer ring. They are positioned axially by jam screws, which bear on the casing heads, and circumferentially by guide pins, which are fitted individually to ensure alignment of the housing bores. The guide pins are secured by pipe plugs. Before the rotor housings can be removed, the housing guide pins must be removed. The outer ends of these pins are drilled and tapped for the application of a pulling tool. Because these guide pins are fitted parts, each pin must be marked as it is withdrawn so that it can be replaced properly.

Before reassembling the unit, carefully inspect and clean all parts of the pump. Be certain that the settings of the lower housing jam screws are correct (check the manufacturer's technical manual or blueprint).

When reassembling the pump, lower the bottom housing, the spacer, and the upper housing into place separately. Ensure that each part seats firmly and that the guide pin slot in each housing registers with the pin hole in the casing. The special tool used to pull the housings can also be used to assemble them. Next, install the housing guide pins and their securing plugs. If new housings are installed, carefully align the bores and fit new guide pins to maintain alignment. You can then set up the jam screws in the upper housing.

Insert the rotors and turn them by hand to see that they are free and do not bind. Binding of the rotors is an almost certain indication that the bores of the housings are not in line or that the

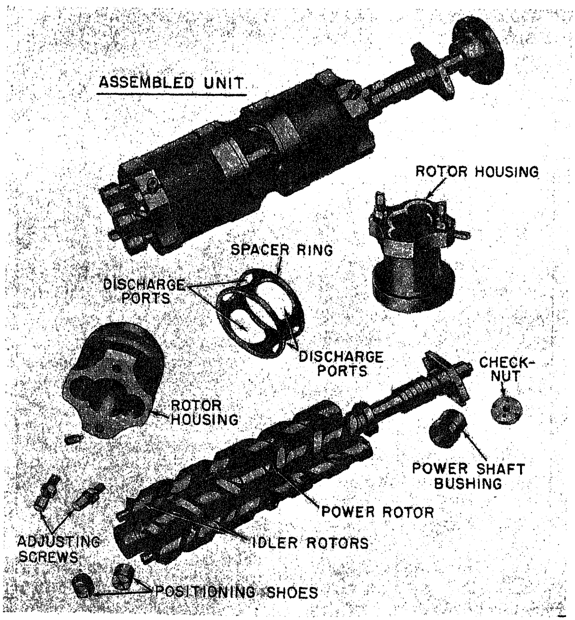

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Figure 6-3.—Rotor assembly for a lube-oil service pump.

guide pins or the housings, or both, have not been properly installed. Install the upper casing head, making sure that the thrust plate and the seal bushing are in place and that the latter is secured by the stop pin provided for that purpose.

When a pump is assembled at the factory, the locating caps on the idlers are set up to establish the proper running positions of the idlers with reference to the power rotor and are then secured by riveting. So long as a set of rotors remains intact, readjustment of the locating cap settings is rarely necessary. Even over long periods of service, wear of the hardened contact surfaces will be negligible.

Whenever new rotors are installed, you must establish the proper locating cap settings. The proper cap settings are such that the lower end surfaces of all three rotors will lie in a common plane when the rotors are properly meshed and the idlers are located centrally with respect to end play in the power rotor.

The cap settings must be established before the rotors are installed. However, the rotors should be inserted in one of the housings for the adjustments, to ensure proper meshing. A tapped hole is provided in the base of each cap. This is done so that the pulling tool, or some other suitably threaded implement, can be used to jack the cap into position. After the settings have been established, rivet the caps into place; you will have to drill the shaft ends for the rivets. Rivet holes are provided in the caps of all idlers supplied by the factory.

SHAFT-DRIVEN LUBE-OIL PUMPS are of the same size and design as the steam-driven pumps but differ in their mountings and drive details.

On ships built since World War II, the attached lube-oil pump is driven from the main reduction gear by an assembly of bevel and spur gears. The driving connection is made by a pinion, mounted on a hub, that is attached to the lower, low-pressure, low-speed pinion quill shaft coupling.

PUMP CONTROL DEVICES

Turbine-driven pumps are fitted with devices to control or limit the speed of the unit or to regulate the discharge pressure of the unit.

SPEED-LIMITING GOVERNORS

Speed-limiting governors are set to give a rated speed at rated load conditions. With the governor properly set, the turbine speed should not exceed the rated speed for any condition of load by more than 5 percent. If the governor will not function within the prescribed limit, it must be overhauled and the cause of faulty operation located and corrected. Speed-limiting governors should be inspected and tested in accordance with the 3-M Systems. They must be tested more often if ordered by NAVSEA, the type commander, or any other proper authority.

Chapter 5 of *Machinist's Mate 3 & 2*, NAVEDTRA 10524-F, contains information on the principles of operation of a centrifugal weight type of speed-limiting governor. Briefly review that chapter if necessary. To set this type of governor, remove the governor lever and the governor cover. The governor spring will then be accessible. If you want to increase the maximum speed of the unit, you must increase the tension of the governor spring by tightening the adjusting nut. With increased spring tension, more centrifugal force will be required to move the weights outward. This in turn moves the sleeve outward against one end of the governor lever and moves the other end of the governor lever inward. These movements close down on the poppet valve and decrease the amount of steam flow to the turbine.

If you decrease the tension on the governor spring, the governor weights will move outward with less centrifugal force. As a result, the maximum speed of the unit will decrease.

There is very little wear in a speed-limiting governor; however, preventive maintenance is required. The governor must be kept clean. Dirt or other foreign matter can foul the spring; more force is then required to move the weights, which allows the pump to overspeed. Rust on the governor lever fulcrum pin causes the lever to bind and not function properly. Keep all pins in the linkage and the valve stem free of paint, rust, and dirt so that the linkage can move freely. Occasionally, make a test to determine whether the poppet valve is leaking. You can make this test by pushing the valve onto its seat by hand. If the valve is leaking, the turbine will continue to rotate.

CONSTANT-PRESSURE PUMP GOVERNORS

Turbine-driven main feed pumps and fire pumps are fitted with constant-pressure governors. These governors control the discharge pressure of the unit by automatically controlling the amount of steam admitted to the turbine.

The following paragraphs deal with maintenance of these governors. For more complete details on operation and maintenance of constant-pressure governors, see the manufacturer's technical manual.

The most common cause of improper operation of constant-pressure governors is dirt or other foreign matter. These materials are carried with the steam into the governor and interfere with the operation of the moving parts. The only remedy is to disassemble the governor and thoroughly clean all parts.

Failure of the governor to properly regulate the pump discharge pressure may also be caused by one or more of the following reasons:

- Leakage around the seating surfaces of the control valve, the main valve, or the threads of their respective seat rings
- A main valve spring or a controlling valve spring that is broken, that is weak, or that has taken a permanent set
- A broken, cracked, or excessively deformed diaphragm
- Improper adjustment of the needle valve
- Too little or too great a clearance between the control valve and its diaphragm
- Clogged ports in the diaphragm chamber
- Binding of any moving parts

This is not a complete list of reasons for failure of constant-pressure governors, but it does cover the most common causes.

When a constant-pressure governor is sluggish or erratic because dirt or other foreign matter is interfering with the free movement of working parts, the governor must be completely disassembled and all parts cleaned. The manufacturer's technical manual gives a step-by-step procedure for disassembly. Use extreme care to remove and clean all parts. Clean the parts with an approved solvent and a soft brush. If this cleaning method fails to remove hardened deposits, use a sharpened tool; but use it with extreme caution.

Pay particular attention to cleaning the seat for the cylinder liner. This liner must fit properly to prevent it from projecting above the body flange. The bore of the main valve guide must also be carefully cleaned. As each part is cleaned, inspect it carefully for excessive wear. If parts must be renewed, use only parts furnished by the manufacturer.

If there is leakage through the control valve or its bushing, steam will flow to the top of the operating piston. This action opens the main valve and holds it open, even though there is no tension on the adjusting spring. The main valve must be able to close completely, or the governor cannot operate properly. The only remedy is to disassemble the governor and stop the steam leakage. In most instances, the control valve must be renewed. If the leakage is through the bottom of the bushing and its seat, the seat must be lapped. A cast iron lap is best for this type of work.

The lap should be rotated through a small angle of rotation, lifted from the work occasionally, and moved to a new position as the work progresses. This will ensure that the lap slowly and gradually rotates around the entire seat circle. Do not bear down heavily on the handle of the lap, and take particular care not to bear sideways on the lap. Replace the compound often, using only clean compound. If the lap develops a groove or cut, redress the lap. Do not lap any longer than necessary to remove all damaged areas.

When you install the control valve and its bushing, remember that the joint between the bottom of the bushing and its seat is a metal-to-metal contact. The bushing must be installed tightly. When it is all the way down, tap the wrench lightly with a hammer to ensure a steamtight joint.

When the controlling valve is installed, check the clearance between the top of the valve stem and the diaphragm. It is absolutely mandatory that this clearance be between 0.001 and 0.002 inch. If the clearance is less than 0.001 inch, the diaphragm will hold the control valve open, allowing steam to flow to the main valve at any time the throttle valve is open. If the clearance is more than 0.002 inch, the diaphragm will not fully open the control valve. This means that the main valve cannot open fully and the unit cannot be brought up to full speed and capacity.

ALWAYS lap in the main valve with the piston in the cylinder liner to ensure perfect centering.

If the damage to the seating surfaces is excessive, install new parts. Use parts supplied by the manufacturer, if available.

If the top flange of the top cap becomes damaged, use extreme care to machine it. See the manufacturer's technical manual for the correct clearances. (See fig. 6-4.)

All seating surfaces must be square with the axis of the control valve seat threads and must have the smoothest possible finish. Before starting the reassembly, be sure all ports in the top cap and diaphragm chamber are free of dirt or other foreign matter. Check to ensure that the piston rings are free in their grooves. Be sure the cylinder liner is smooth and free of grooves, pits, or rust.

When installing the cylinder liner, make certain that the top of the liner does not extend above the top of the valve body. The piston must work freely in the liner; if there is binding, the governor will not operate satisfactorily. Renew the controlling valve spring and the main valve spring if they are weak, broken, or corroded or if they have taken a permanent set. If necessary, renew all diaphragms. If the old diaphragms are used, install them in their original position; do not reverse them.

When lapping the main valve, use a fine grade of grinding compound. Lap the valve as little as possible...

ernor. All clearances must be as designed if the governor is to operate satisfactorily. Check each moving part to ensure freedom of movement.

When the governor is reassembled, test it as soon as possible so that you can make any necessary corrections.

SAFETY PRECAUTIONS FOR OPERATING PUMPS

Carefully following the list of safety precautions listed below will help prevent casualties to the pumps on your ship.

- If relief valves are fitted, ensure that they function at the designated pressure.

- Never attempt to jack a pump by hand when the steam valve to the driving unit is open.

- Do not render inoperative the overspeed trip or the speed-limiting or speed-regulating governor.

- Ensure that overspeed trips are set to shut off steam to the unit when the rated speed is exceeded by 10 percent.

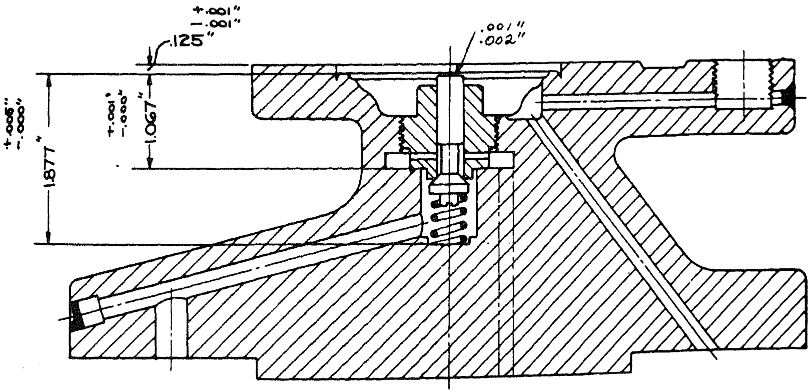

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Figure 6-4.—Important points in cleaning and reassembling a top cap assembly.

- Ensure that speed-limiting and speed-regulating governors are set to limit pump speed to rated speed under rated conditions and that rated speed is not exceeded by more than 5 percent for any loading condition.

- Ensure that drains are open and that steam and exhaust root valves are wired shut and tagged before opening the turbine-driven unit steam end.

- Never operate a positive displacement rotary pump with a discharge valve closed unless the discharge is protected by a properly set relief valve.

- Never use a jacking bar to start a reciprocating pump while the steam valve to the pump is open.

CHAPTER 7

DISTILLING PLANTS

As a Machinist's Mate 1 or C, you will operate, troubleshoot, and repair the submerged tube and flash types of distilling plants used by the Navy.

The type and size of distilling plants used on each class of ship are determined by many factors. Some of these are—type of propulsion plant, number of personnel assigned, safety, and reliability. For more information than is provided in this training manual, see the manufacturer's technical manual for the type of plant on your ship.

SUBMERGED TUBE DISTILLING PLANTS

The low-pressure, submerged tube distilling plants vary considerably on different ships; but the principle in all cases is the same. The handling of abnormal operating conditions and the maintenance procedures are basically the same. In almost all instances, the personnel who stand watches on distilling plants are also responsible for their upkeep and maintenance. This allows you to detect abnormal operating conditions before they reach advanced stages. It is your responsibility to locate any operating trouble and to make the necessary adjustments or repairs.

TROUBLESHOOTING A SUBMERGED TUBE PLANT

Naval distilling plants are designed to produce distillate of very high quality. The chloride content of distillate discharged to the ship's tanks must not exceed 0.065 equivalent per million. Any distilling unit that cannot produce distillate of this quality is not operating properly.

Steady operating conditions are essential to the satisfactory operation of a distilling unit. Fluctuations in the pressure and temperature of the first-effect generating steam will cause fluctuations in the pressure and temperature throughout the entire unit. These fluctuations may cause priming, with increased salinity of the distillate. They may also cause chaotic operation of the feed and brine pump. Rapid fluctuations of pressure in the last effect also tend to cause priming.

Except under emergency conditions, no plant should be forced beyond its rated capacity. Such forcing requires higher steam pressures, which produce higher temperatures that cause more rapid scaling of the evaporator tubes. The same is true if the unit is operated at less than designed vacuum—the heat level rises throughout the unit, causing an increased tendency toward scale formation.

In operation, the elements of any plant are interdependent because of the heat and fluid balances throughout the plant. Adjustment of any one control can produce widespread effects on these balances. For example, an increase in the feeds to the first effect raises the liquid level in the first effect. More heat is required to raise the feed to the boiling point. Less heat is then available for evaporation in the first-effect shell, and a smaller amount of heat flows to the second-effect tube nest. These changes will work out to a new balanced condition, but other adjustments will be required to make the new balance satisfactory. Under such circumstances, overcontrolling can cause many readjustments. It is best to make adjustments singly and in small increments, allowing enough time between each adjustment for the conditions to become steady.

A failure to get full-rated capacity is one of the most frequent troubles in the operation of a distilling plant. The trouble may be very difficult to remedy since it may be caused by a combination of things. The following factors promote low output of the distilling plant:

1. Low steam pressure above the orifice
2. Low vacuum in the first-effect tube nest
   a. Air leaks
   b. Improper water levels in the evaporator shell

c. Scale formation on the evaporator tube nest
    (1) Improper feed treatment or lack of feed treatment
    (2) Brine density maintained above 1.5/32
3. Improper water levels
4. Improper venting of the evaporator tube nest
5. Low vacuum in the last-effect shell

Steam Pressure

A distilling plant cannot maintain its full output unless it is supplied with dry steam at the designed pressure. The orifices must pass the proper amount of steam to ensure plant output with a pressure of about 5 psig above the orifice. Inspect the orifice annually. During the inspection, measure the orifice and compare the reading with the figure stamped on the plate. Review the orifice if necessary.

If the steam pressure above the orifice varies, locate and correct the source of trouble.

Check the diaphragm control valve to determine whether or not it is operating properly. If it is functioning properly and the pressure cannot be maintained above the orifice, the plant is not getting enough steam.

The auxiliary exhaust steam supply for the distilling plants, after passing through the regulating valve, is usually slightly superheated. This is caused by the pressure drop through the reducing valve and orifice plate. A small amount of superheat has little or no effect on operation or scale formation. However, if it is necessary to use live steam, use the installed desuperheater spray connection to control the superheat. The water for desuperheating must be taken from the boiler feed system, preferably from the first-effect tube nest drain pump. Water for desuperheating must never be taken directly from the fresh water distilled by the distilling plant.

Fluctuations in the first-effect generating steam pressure and temperature cause fluctuations of pressure and temperature throughout the entire plant. The fluctuations may cause priming, with increased salinity of the distillate, as well as erratic water levels in the shells. Proper operation of automatic pressure regulators in the steam supply line will eliminate fluctuation of the pressure in the first-effect heat exchanger.

First-Effect Tube Nest Vacuum

The pressure in the first-effect tube must range from 16 inches of mercury, with clean tubes, to 1 and 2 inches of mercury as scale forms. The output of a submerged tube type of distilling plant is not greatly reduced until the deposits on the tubes have caused the vacuum to drop to about atmospheric pressure. When the first-effect tube nest vacuum is lost entirely, there is a great reduction in output. If the reduction in vacuum is caused by scale and not by improper operating conditions, the tubes must be cleaned.

Keep the vacuum in the first-effect tube nest as high as possible. This helps keep scale formation to a minimum, enabling the plant to operate at full capacity.

Always correct a vacuum reduction that is caused by any factor other than deposits on tube surfaces. This will reduce deposits and greatly prolong the time between cleanings. The primary factors affecting the first-effect tube nest vacuum are air leakage, low water level in the evaporator shells, improper venting of the evaporator shells, scale or other deposits on the tubes, and improper draining of the evaporator tube nests.

Loss of vacuum resulting from deposits on evaporator tubes should be gradual. Under normal conditions, there will be no large change of vacuum for any one day's operation. A sudden drop in vacuum can be traced to causes other than scale deposits.

The generating steam circuit operates under vacuum and is subject to air leaks. Leaks from the steam side of the first-effect tube nest to the first-effect shell space will cause losses of capacity and economy. Air leaks from the atmosphere into the generating steam line (downstream from the orifice plate), the first-effect tube nest front header, and the first-effect tube nest drain piping will cause a loss of vacuum and capacity. Air leaks in this part of the distilling plant may be less noticeable than air or water leaks elsewhere because the effect on the plant is similar to the scaling of the tube surfaces.

Proper Water Levels

A reduced first-effect tube nest vacuum can result from too low a water level in any evaporator shell. On older plants, the water levels are controlled by manually regulating the feed valves. On newer ships, the water levels are automatically controlled by Weir types of feed regulators. Inability to feed the first effect is usually caused

by scale deposits in the feed lines between the effects. It is important that the gauge glass and the gauge glass fittings be kept free of scale that cause false water-level indications. Air leaks around the gauge glass will also cause false level indications in the gauge glass.

Once the distilling plant is in operation, the feeding must be maintained at a steady rate. Sudden rising of the water levels or too high a water level will cause priming, or a carry-over of small particles of brine with the vapor. The level of water in the shell must be carried at the highest level that can be held and still prevent priming, because scale will form rapidly on exposed tube surfaces.

The pressure differential between the first and second effects permits the second-effect feed to discharge into the second-effect shell. A partial or total loss of pressure differential indicates air leaks between the first- and second-effect shells in the two-effect distilling plants. Large air leaks between the first effect and second effect can be readily detected; the vacuum gauge for the first effect will read approximately the same as the vacuum gauge for the second effect. Large air leaks of this type will disrupt the operation of the plant. They must be located and repaired before the plant will operate properly.

Proper Venting of Various Units

Pay careful attention to the problem of air collection in various parts of the distillery unit. Air is mixed with water and steam and enters the unit at various parts of the system. Since air is heavier than water and lighter than steam, it tends to settle between the two, usually in the following points:

- The evaporator heat exchange and drain regulator
- The high points of the feed line
- The water side of the distillery condenser
- The vapor and evaporator heat exchanger drain feed heater

Air vents should be cracked open to ensure adequate venting. If an evaporator does not reach its rated capacity, it is usually caused by a failure to vent the accumulated air. An accumulation of air in any part of the system causes a loss in capacity and erratic operation. Excessive venting of an evaporator heat exchanger can mean reduced economy. The proper setting of vent valves during operation is largely a matter of experience.

Last-Effect Shell Vacuum

Most manufacturers' technical manuals call for a vacuum of approximately 26 inches of mercury in the last-effect shell when the temperature of the seawater is 85 °F; the vacuum should be higher when the seawater is colder. Lower vacuum can generally be traced to one of the following problems: air leaks, improper operation of air ejectors, insufficient flow of seawater, and ineffective use of the heat transfer surface in the distilling condenser.

MAINTENANCE

The plant will operate at full output for relatively long periods of time only if every part is maintained in proper operating condition. You can ensure this by periodic inspections and tests and by cleaning or replacing parts as necessary. Some parts require more attention than others. Some of the more common plant maintenance tasks are discussed below.

Testing for Air Leaks

The importance of eliminating air leaks cannot be overemphasized. Many distilling plant problems are caused directly by air leaks in the shells of distilling plants. These leaks cause a loss of vacuum and capacity. Be very careful when you make up joints, and keep them tight. Periodically test joints under pressure for leaks.

There are several ways to test for air leaks in the tube nests, heat exchangers, shells, and the piping systems. When the plant is in operation, you can use a candle flame to test all joints and parts under vacuum. When the plant is secured, you can use an air-pressure or soapsuds test on the various component parts. The manufacturer's technical manual describes how the various parts of the plant can be isolated and placed under air pressure.

You can also detect air leaks by hydrostatic tests of the various parts of the plant. When performing air tests or hydrostatic tests, do not exceed the maximum limit of the test pressures specified by the manufacturer.

Testing for Saltwater Leaks

If you find a leak in a heat exchanger, locate the defective tube(s) by means of an air test or a hydrostatic test, in accordance with the recommended procedure in the manufacturer's instructions. Use blueprints to study the construction details of the individual heat exchanger.

As soon as a leaky tube has been located, plug it at both ends. Use special composition plugs that are provided in the allowance repair parts.

Plugging the tubes reduces the amount of heating surface; therefore, the heat exchanger will not give satisfactory performance after a number of tubes have been plugged. It will then become necessary to retube the heat exchanger. Under normal conditions, this work should be accomplished by a naval shipyard or tender. However, repair parts and a number of special tools are included in the Ship's Allowance List so that emergency repairs can be made.

To find which of the tubes within a removable tube bundle is leaking, you need to test the individual bundles hydrostatically. If the leak is in a removable bundle (vapor feed heaters when within an evaporator shell, evaporator tube nests, distilling condensers on Solo-shell end-pull plants), withdraw the bundle and apply a hydrostatic test at full pressure. Apply 50 psi on the tube side.

If a leak occurs in a nonremovable tube bundle (distillate coolers, air-ejector condenser, external vapor feed heaters), remove the tube nest covers and apply a full test pressure of 50 psi on the shell side of the unit.

If a nonremovable distillate condenser bundle is within an evaporator shell, remove the tube nest covers and apply a full test pressure of 30 psi to the evaporator shell.

AIR-EJECTOR OPERATION

In operation, air ejectors require little attention. However, the following points should be noted:

The steam pressure at the nozzle inlet must not be less than that for which the ejector is designed (and which is stamped on the nameplate). There may be a substantial pressure drop in the steam line, and it may be necessary to carry a higher pressure on the gauge. However, pressures at the air-ejector nozzle may be 10 to 15 psig higher than the minimum specified by the manufacturer.

The primary causes of air-ejector problems are low steam pressure, wet steam, an obstructed nozzle, or a clogged steam strainer. Such problems are indicated by a lower than normal vacuum. The problem may be caused by low steam pressure or wet steam. If so, increase the steam pressure or provide suitable drainage, either by installing a trap or by manual means. If the nozzle or steam strainer is clogged, remove it and clean it. Most plants have two sets of air ejectors; this permits the use of the plant on one unit while the second is cleaned or repaired. However, some of the latest plants have only one set of air ejectors.

When it is necessary to clean air-ejector nozzles, use the special nozzle reamers furnished to each ship for this purpose. Never use sharp-edged tools to clean nozzles. You will damage the nozzle surfaces and impair the efficiency of the air ejectors.

You will find a procedure for testing air ejectors in the manufacturer's technical manual. In general, follow the same maintenance procedures for distilling plant air ejectors as for air ejectors for main condensers.

The air-ejector strainer is usually an integral part of the air-ejector inlet. It should be inspected and cleaned in accordance with the planned maintenance system. When a new plant is first put into operation, the strainer may require cleaning every day or even more frequently. A dirty strainer will cause a reduced or fluctuating vacuum. If a strainer or a nozzle becomes damaged, replace it with a new one.

INSUFFICIENT CIRCULATING WATER

An insufficient flow of circulating water is indicated if the temperature of the water rises more than 20 °F in passing through the condensing section of the distiller condenser. The last-effect shell pressure is directly dependent upon the distiller condenser vacuum. The vacuum is dependent upon the temperature and quantity of the circulating water and the proper operation of the air ejectors. If the overboard discharge temperature of the distiller condenser circulating water is too low, it will cause a loss of efficiency in the distilling plant. The overboard discharge temperature should be kept as high as possible without exceeding the desired 20 °F temperature rise through the distiller condenser. In addition, limiting the quantity of circulating water tends to prolong the service life of the tubes and tube sheets. When problems occur that are not caused

by improper operating procedures, inspect the condenser circulating water system to determine the cause of faulty operation.

Carry out preventive maintenance procedures to ensure that the circulating water pump is maintained in good material condition. The maintenance and repair of this pump are similar to that for the other pumps of the plant.

Carry out routine procedures to ensure the proper setting and maintenance of the back-pressure regulating valve. If this valve is not functioning properly, disassemble it and repair or replace parts as needed before it interferes with the operation of the distilling plant.

To ensure that the condenser circulating water system is clean and free from scale and foreign matter, inspect the piping at regular intervals. Inspect and clean the strainers in accordance with the planned maintenance system. This is to prevent accumulations of foreign matter from interfering with the proper operation of the distilling plant.

IMPROPER DRAINAGE

The distilling plant may not produce designed output even when the pressure above the orifice is 5 psig and the first-effect tube nest vacuum is several inches of mercury. If so, this always indicates improper drainage of the distiller condenser or of one of the evaporator tube nests subsequent to the first effect. Complete flooding of the flash chamber gauge glass also indicates improper draining of the condenser.

Each regulator is installed to prevent steam or vapor from being blown through the heat exchanger before it has condensed and given up its latent heat. Improper operation may result either in drains being stopped up or steam or vapor being blown through the heat exchanger. The stoppage of drains in the first effect causes condensate to back up and reduce the heating surface. The result is the same in the second effect. In addition, since the drains make up a part of the distilled-water output, the capacity is reduced. Since these regulators all operate under vacuum, be very careful that all joints are free from air leaks.

CONSTANT BRINE DENSITY

The concentration of brine in the evaporators, to a certain extent, has a direct bearing on the quality of the distillate. Since varying quantities operating conditions, the quantity of brine discharged and the brine density must be kept as constant as possible.

If the brine concentration is too low, there will be a loss in capacity and economy. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator heating surfaces, and the quality of the distillate will be impaired.

The brine density, which should never exceed 1.5/32, is dependent mainly on the quantity of brine pumped overboard and the amount of fresh water being produced. Check the density frequently during each watch and adjust it to the required density. On older distilling plants the brine density is adjusted by means of a hand-controlled valve located in the discharge line of the brine overboard pump.

Frequent changes of brine density tend to disrupt steady performance of the plant. Therefore, you should make only very small changes. The proper setting for a specific plant should be learned from experience and maintained as practical.

A salinometer is used to measure the degree of salinity or the concentration of brine. Check accuracy of the salinometer occasionally by placing it in distilled water. If it is accurate, it should sink to the zero mark on the scale corresponding to the temperature of the water.

FLASH TYPES OF DISTILLING UNITS

The flash type of evaporator, like all distilling plants, removes salts and other impurities from raw seawater by evaporation and condensation. The water is boiled and converted to steam, which is then condensed to form distilled water. The flash evaporator is different from other distilling plants; evaporation takes place at temperatures well below the normal boiling point of water and without the use of submerged heat transfer surfaces.

In the flash type of distilling plant, the temperature of the water is never raised beyond 175 °F. It is only raised to this temperature within the last pass of tubes of the saltwater heater. Flash evaporation takes place at temperatures as low as 104 °F. In addition, there is no boiling on heat transfer tube surfaces. This greatly reduces scale formation and prolongs operation at maximum

The term *flash evaporation* means that water is converted to steam as it enters an evaporating chamber, without further addition of heat. Flashing at low temperatures is possible only when a vacuum is maintained in the chamber; the boiling point of water decreases as the pressure in the chamber is reduced. As in other methods of distillation, a portion of the water remains behind in the evaporating chamber and is taken off as brine.

PRINCIPAL COMPONENTS

The unit discussed in this section is a five-stage plant in which feedwater is flashed to vapor in five evaporator stages at successively lower pressures.

The connections, or passages, between evaporator stages are the feedwater and distillate loop seals. These permit the flow of feedwater and distillate from stage to stage while preserving the varying degrees of vacuum in each stage.

The condensers are mounted on top of each stage between the front and rear water boxes. Feedwater flows through the tubes in six passes. It enters at the lowest tubes at the front of the condenser, reverses direction at the water boxes three times, and leaves at the top of the tubes in the condenser. Each condenser has a pet cock for venting entrained air or noncondensable gases.

The evaporator stages become larger in the direction of reduced pressure. The feedwater loop seals that extend from the bottom of evaporator stage one through stage four are visible as cylinders. An evaporator drain is located in the center of the dished bottom of each loop seal. The flanged brine outlet from the evaporator is at the bottom of the fifth stage.

The distillate loop seal between the distillate collection trough of one stage and the condensers of the following stages also protrude below the bottom of the evaporator.

If the salinity of the distillate reaches 0.065 epm per gallon, a warning device indicates the high salinity. The salinity cell shutoff valves permit withdrawal and descaling of the salinity cells without securing the unit.

Although the condenser at each stage produces an equal amount of distillate, the amount flowing from each stage is larger than the preceding, as in the distillate cooler. Therefore, the loop seal piping grows progressively larger.

The total distillate production of the five stages is withdrawn from the bottom of stage five, pumped into the shell of the distillate cooler, and passed on to the storage tanks.

The DISTILLATE COOLER is a heat exchanger of the shell and tube type. The heat of the hot distillate flowing around the tubes is transferred by conduction to the cooler feedwater flowing through the tubes.

Distillate flows into the shell space surrounding the tubes through an inlet near the feedwater outlet. The distillate is retained in the cooler long enough to transfer its heat through the tubes by vertically placed baffles as it flows from the top to the bottom of the cooler.

Thermometers are mounted on the inlet and outlet piping of the cooler. Another thermometer is mounted on the feedwater inlet piping.

As the distillate leaves the cooler, and if the salinity does not exceed 0.065 epm per gallon, it is pumped to storage tanks. If the salinity exceeds 0.065 epm per gallon, a solenoid trip valve, operated by a salinity indicating cell, dumps the distillate to the bilges or waste tank. This process continues until the salinity is at or below 0.065 epm per gallon. At that time, the operator should manually engage the dump valve so the distillate will go to the storage tank.

Pet cocks are located on each end of the cooler to bleed off any accumulation of air or noncondensable gases.

The FEEDWATER PREHEATER is a gas or liquid heat exchanger of the shell and tube type, similar in design to the distillate cooler. The preheater is located in the feedwater line between the condenser of the first evaporator stage and the saltwater heater.

High-pressure ship's steam, first used by the air ejectors to evacuate the stage evaporators, is piped into the preheater shell. A series of five baffles, spaced close together in the top steam outlet, reduces the velocity of the steam that condenses on the outside of the heat transfer tubes.

Feedwater that has already been partially heated in the tubes of the distillate cooler and the five-stage condensers flows through the tubes of the preheater via the front water box in a single pass. There it acquires the heat of condensation of the air-ejector steam before leaving the preheater at the rear water-box outlet.

A salinity cell, set to energize at 0.10 epm, operates a shutoff valve in the piping below the condensate outlet. The valve dumps high-salinity water to the bilge or a drain tank. A 6-inch loop seal in the condensate line ensures that the salinity cell is submerged at all times.

A thermometer is located on the front of the preheater. A pet cock for venting is also located on the water box.

The SALTWATER HEATER is a gas or liquid heat exchanger that raises the feedwater temperature before it enters the flash chamber of the first evaporator stage. The saltwater heater is mounted on the operating end of the evaporator and extends the full width of the unit. Feedwater enters and leaves the heater from the front water box after making four passes through the heater.

Four thermometers are installed on the heater. Two measure the feedwater inlet and outlet temperature. A third, mounted on the heater shell, measures the steam temperature surrounding the tubes. A fourth, mounted on top of the heater shell, measures the temperature of the desuperheating temperature in the steam side.

Low-pressure steam in the heater passes through an orifice that provides, within limits, a uniform flow of steam. It then flows past the desuperheater nozzle, which reduces steam temperature in the shell of the heater. Steam pressure is indicated by a pressure gauge on the operating panel.

The entering steam is directed along the length of the tubes by impingement baffles, which prevent erosion of the tubes. Steam condenses on the tubes and falls to a condensate well at the bottom of the heater shell. (A drain regulator of the float type controls the level of the condensate in the well. A salinity cell, set to energize at 0.10 epm, controls a shutoff valve located in the ship's piping between the drain pump and regulating valve.) The desuperheater atomizes the heater condensate in the low-pressure steam side of the heater.

The saltwater heater provides feedwater to the inlet of the first evaporator stage flash chamber, and the amount of heat from the steam is constant; therefore, the feedwater flow through the heater must be adjusted according to the inlet temperature. The feedwater flow is controlled by a valve on the outlet side of the heater.

The air-ejector PRECOOLER is a gas or liquid heat exchanger. It cools noncondensables and condenses steam drawn from the first three evaporator stages and the saltwater heater by a two-stage vacuum-producing air ejector.

The precooler uses feedwater pumped into the distilling unit as a coolant. The water makes six passes through heat transfer tubes, entering and leaving at the front end of the cooler.

Steam and noncondensables are drawn into the cooler at the top near the rear of the cooler. The flow of hot gases is directed around the transfer tubes for efficient heat transfer by impingement baffles at the inlet and seven vertical baffles through which the tubes run.

Condensate collects on the tubes and drops to the bottom of the shell. A salinity cell operates a shutoff valve in the precooler condensate line. The valve dumps the condensate to the bilge or drain tank when the salinity is greater than 0.065 epm.

The outlet for noncondensables is mounted on the top of the shell. It is flanged to the suction chamber of the first ejector of the two-stage air-ejector system. The two air ejectors produce a vacuum in the precooler that results in the flow of steam and noncondensables from the evaporator. A thermometer is mounted on the feedwater inlet of the cooler.

Cooling water from the air-ejector precooler flows into the AFTER-CONDENSER, the fifth of the heat exchangers mounted on the evaporator. The after-condenser completes the condensation of any air-ejector steam not condensed in the precooler and cools noncondensable gases before venting them to the atmosphere. It enables the unit to operate without emission of steam from the evaporator.

Cooling water enters and leaves the after-condenser through an inlet in the front and an outlet pipe in the rear of the condenser.

Air-ejector steam and noncondensable gases enter the shell side through an inlet in the front of the unit. Noncondensable gases are vented through a valve on the rear of the unit. A series of vertical baffles directs the steam around the tubes on which it condenses. Condensate is removed through bottom outlets on both ends of the condenser.

A salinity cell set to operate at 0.10 epm controls a shutoff valve below the condenser.

Three high-pressure, steam-operated, vacuum-producing AIR EJECTORS are mounted on the precooler side of the evaporator unit. The ejector system consists of a single-stage (booster) air-ejector and a two-stage air-ejector arrangement in which the steam outlet from one air ejector is flanged to the suction side of the other.

The single-stage ejector uses ship's steam to draw vapor and noncondensables from evaporator stages four and five. Gases are drawn from the evaporator through a vapor duct in each distillate collection trough so that a minimum of steam is withdrawn. Pipes from stages four and five lead to a bronze tee flanged to the ejector.

The single-stage ejector steam and entrained gases leave the ejector outlet tubing, flow through a check valve, and reenter the evaporator shell through the top of stage three. From there, they are piped into the bottom of the stage three condenser section.

This arrangement allows the single-stage ejector to produce the high degree of vacuum required in stages four and five. An ejector discharging into a vacuum is able to achieve a higher degree of vacuum than one discharging to atmosphere. A vacuum of 28 inches of mercury is required in stage five.

The two-stage ejector draws noncondensables from the saltwater heater and the first three evaporator stages. The noncondensables from stages four and five are directed back into stage three. Therefore, the two-stage ejector actually handles all noncondensables within the unit.

The suction chamber of the second ejector is flanged to the noncondensables outlet of the precooler. The gases pass through the precooler before they are entrained in the air-ejector steam. The two-stage ejectors use ship's steam and produce a vacuum in the precooler slightly greater than in the first evaporator stage.

Orifice plates of varying sizes are flanged into the piping from the evaporator stages and saltwater heater leading to the air ejectors. These plates prevent the air ejectors from withdrawing an undue amount of steam from the evaporator along with the noncondensables.

The discharge of the second ejector is flanged to the suction chamber of the third ejector. The discharge of the third ejector is flanged to piping that contains a check valve and runs diagonally across the top of the evaporator shell to the air-ejector steam inlet of the preheater shell near the front water box.

The pressure of ship's steam piped to the ejectors is indicated on the independently mounted pressure gauge panel. Line pressure to the air ejectors must be maintained at or above 135 psig; a lower pressure will cause unstable operation of the ejector and will affect the vacuum in the evaporator.

A DUPLEX STRAINER, located in the ship's feedwater inlet piping, removes solid matter from seawater by filtering through one of the two perforated and screened bronze baskets. Basket wells are located in the body or housing of the strainer on either side of the centrally located flanged inlet and outlet.

A lever handle between the wells directs the feedwater into the left- or right-hand well. When one basket becomes clogged, flow is switched to the other. The clogged basket should be removed and cleaned.

An inlet and outlet angle type of RELIEF VALVE is flanged into the feedwater inlet between the feedwater pump and the air-ejector precooler. The valve is set to open at 75 psig. This prevents pressure buildup from an obstruction in the feedwater lines or accidental operation of the feedwater pump with the feedwater control valve closed.

MAINTENANCE OF FLASH TYPES OF UNITS

Many of the maintenance procedures for a flash type of distilling plant are similar to those for a submerged tube plant. Both types of plants are subject to air leaks, saltwater leaks, and malfunctioning pumps and other auxiliary equipment. Some of the more important maintenance problems are covered in the following paragraphs.

Air Leaks

All parts of the distilling plant, except the circulating, feedwater and freshwater lines, operate under a vacuum. Be very careful to prevent air leaks that may seriously interfere with the proper operation of the plant.

The brine overboard and distillate pumps take their suction from points of relatively high vacuum. Air leaks in the piping to these pumps are particularly objectionable and must be eliminated. A small amount of air entering these lines, even though it is insufficient to affect the distilling plant vacuum, may cause the pump to lose suction. Do not overlook leaks in the lines to the pump suction gauges.

Apply an 8- to 10-psig low-pressure hydrostatic test to the entire system. Do this according to the planned maintenance system and at any other time when you suspect an air leak. The saltwater circulating pump can be used to apply the pressure.

Pumps

Proper operation of all pumps is essential for the successful operation of the distilling plant. The effect of air leaks into the suction line of the pumps has been discussed in the preceding paragraph. Proper operation of the water-sealed gland lines and proper maintenance of the glands themselves are necessary for dependable operation

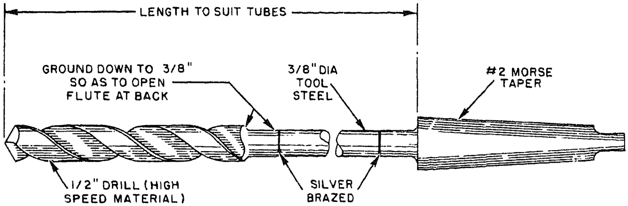

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Figure 7-1.—Tool for removing scale inside tubes.

of the pumps. General information on operation and maintenance of pumps may be found in *Machinist's Mate 3 & 2*, NAVEDTRA 10524-F, and in this training manual. However, consult the manufacturer's technical manual for details of any specific pump.

Saltwater Leakage

You may find salt-water-to-distillate or salt-water-to condensate leaks at any of the various tube bundles. These will be immediately indicated by an alarm bell and a red light that shows which cell has a conductivity increase. The cells are located downstream from each tube bundle. Tube leaks are usually caused by damaged or corroded tubes or by improper expansion of tubes into tube sheets.

Faulty tubes may be sealed with plastic tube plugs or removed and replaced. Follow standard Navy procedures, as in chapter 9581 of *Naval Ships' Technical Manual.*

Cleaning Heat Exchangers

The tubes of the distillate cooler, air-ejector condenser, and the stage condensers operate with comparatively cool salt water inside them and will seldom require cleaning. However, the seawater in the saltwater heater is at a higher temperature. These tubes will occasionally require cleaning to remove the hard scale on the inside of the tubes. A special tool (fig. 7-1) is furnished for this purpose.

The procedure for cleaning saltwater heaters is as follows: Remove the waterheads. Insert the special cleaning tool in the tube and drive it with a 250- to 300-rpm motor. The motor should be of the reversible type. Feed a light stream of water into the opposite end of the tube to wash the scale from the cutting tool and out of the tube. A light stream of compressed air may be substituted in place of the water. Take care not to drive the tool too fast and be certain that the tool is straight when you insert it into the tube.

Perform an 8- to 110-psig hydrostatic test on the shell of the saltwater heater before replacing the heads. If a greater test pressure is used, the relief valve will have to be plugged or removed.

Cleaning Feed Boxes

If feed flow is below normal and the distiller feed pump discharge is normal, the first-stage flash orifices may be plugged. If water backs up into the first stage, the second-stage orifices may be plugged. However, the second-stage orifices are larger and will not be as readily plugged. Water backing into the first stage may also be caused by insufficient pressure difference between the stages.

The temperatures in the feed boxes are well below the range in which saltwater scale forms. Therefore, the only plugging or fouling at the orifices should come from the foreign matter in the system. Should the orifices in either stage become plugged, remove the access plate at the front of the unit, remove the perforated plates from the feed box, and remove the obstructing material from the orifices. The feed boxes are constructed so that the front can be readily removed for access to the orifices.

CHAPTER 8

REFRIGERATION AND AIR CONDITIONING

As an MM 3 & 2, you learned the principles of refrigeration and air conditioning and the components and accessories that make up the system. You learned how to start, operate, and secure refrigeration plants. In addition, you performed routine maintenance jobs such as checking for noncondensable gases, pumping down the system, using the halide torch to test for leaks, and changing the lubricating oil in refrigeration compressors. As you advance in rate, you will be expected to have a greater knowledge of the construction and operating principles of refrigerating equipment. You will perform more complicated maintenance jobs, make repairs as required, determine the causes of inefficient plant operation, and accomplish the necessary corrective procedures.

This chapter provides information that supplements related information in other training manuals that apply to your rating and that is related to the qualifications for advancement. Information is included on the construction and maintenance of refrigeration and air-conditioning equipment and the detection and correction of operating difficulties.

Refer to the manufacturer's technical manual for details of the plant on your ship.

COMPRESSORS

Many different types and sizes of compressors are used in refrigeration and air-conditioning systems. They vary from the small hermetic units used in drinking fountains and refrigerators to the large centrifugal units used for air conditioning.

One of the most common compressors on modern ships is a high-speed unit with a variable capacity. This compressor is a multicylinder, reciprocating design with an automatic device built into the compressor to control its output. This automatic capacity control provides for continuous compressor operation under normal load conditions.

CAPACITY CONTROL

The capacity of the compressor is controlled by unloading and loading the cylinders. This is a very desirable design feature of the unit. If the compressor had to be started under a load, or with all cylinders working, a much greater amount of torque would be required, and it would be necessary to have a much larger drive motor. Also, if the compressor ran at constant capacity or output, it would reach the low-temperature or low-pressure limits or be constantly starting and stopping, thereby putting excessive work on the unit.

Unloading of the cylinders in the compressor is accomplished by lifting the suction valves off their seats and holding them open. This method of capacity control unloads the cylinders completely and still allows the compressor to work at as much as 25 percent of its rated capacity.

Unloader Mechanism

When the compressor is not in operation, the unloader mechanism is in the unloaded position. (Fig. 8-1 is an example of one type of system.) The mechanism is operated by oil pressure from the capacity control valve. The oil pressure pushes the unloader spring against the unloader piston. This action moves the unloader rod to the left, thereby rotating the cam rings. As the cam rings are rotated, the lifting pins are forced upward, raising the suction valve off its seat. The suction valve is held in this position until the compressor is started and oil pressure of approximately 30 psi is reached. At that time, the oil pressure from the capacity control valve pushes the unloader piston back to the right against the unloader spring. The motion transmitted through the push rod rotates the cam ring. This lowers the lifting pins and allows the suction valve to close or operate normally and the cylinder to become loaded (fig. 8-2). On most compressors the unloader is connected to the cylinders in pairs.

Capacity Control Valve

The capacity control valve (fig. 8-3) is located in the compressor crankcase cover. The valve is

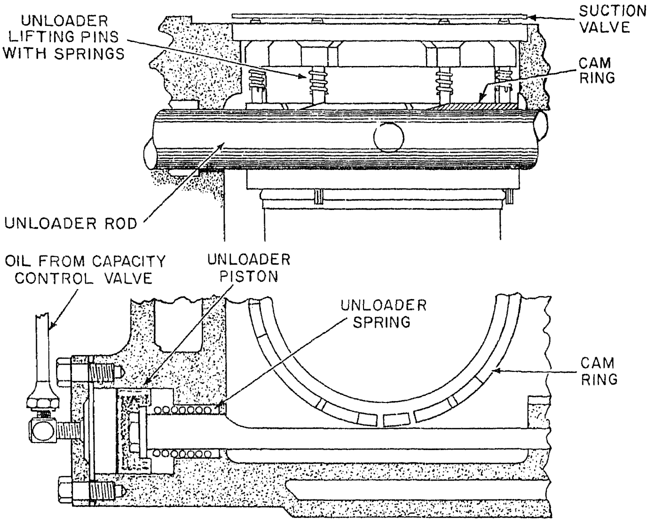

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Figure 8-1.—Unloader mechanism in unloaded position.

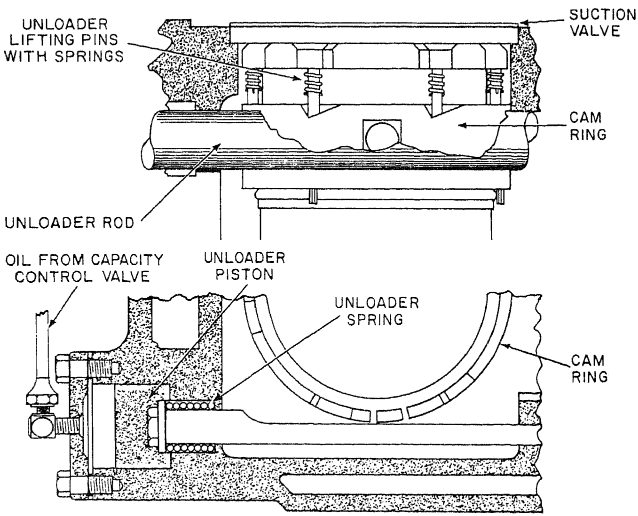

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Figure 8-2.—Unloader mechanism in loaded position.

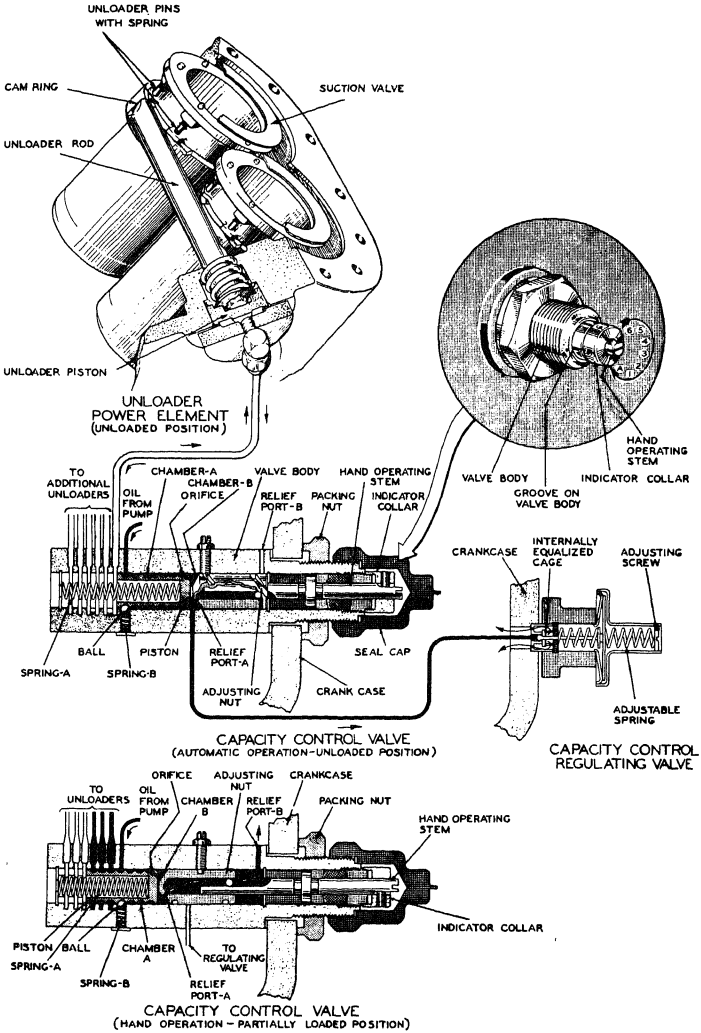

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Figure 8-3.—Capacity control system.

actuated by oil pressure from the main oil pump. It admits or relieves oil to or from the individual unloader power elements, depending on suction or crankcase pressure. Referring to figure 8-3, when the compressor is at rest, the two cylinders equipped with the unloader element will be unloaded and remain unloaded until the compressor is started and the oil pressure reaches normal operating pressure.

The high-pressure oil from the pump enters chamber A of the capacity control valve. It then passes through an orifice in the top of the piston to chamber B, forcing the piston to the end of its stroke against spring A. When the piston of the valve is forced against spring A, the circular grooves that form chamber A are put in communication with the unloader connections. This admits high-pressure oil to the unloader cylinder and actuates the unloader mechanism.

A capacity control regulating valve controls oil pressure from the capacity control valve. It is connected to the crankcase and has an oil-connecting line to chamber B of the capacity control valve. As the crankcase or suction pressure pulls down slightly below the setting of the regulating valve, the regulator opens and relieves oil pressure from chamber B of the capacity control valve. This permits spring A to push the capacity control piston one step toward chamber B, uncovering the unloader connection nearest the end of the capacity control valve. This relieves oil pressure from the power element and allows the power element spring to rotate the cam rings and unload the cylinder.

If the suction pressure continues to drop, the regulator will relieve more oil pressure and unload more cylinders. If the heat load increases, the suction pressure will increase, causing the regulating valve to close and load more cylinders.

MAINTENANCE

As an MM1 or MMC, maintaining the refrigeration and air-conditioning plants may be one of your responsibilities. To do this, you must understand the maintenance procedures. In most instances, personnel who are assigned to maintain refrigeration plants are graduates of the Navy's air-conditioning and refrigeration school. This school teaches most operating and main-

Testing Suction and Discharge Valves

Faulty compressor valves may be indicated by either a gradual or a sudden decrease in the normal compressor capacity. Either the compressor will fail to pump, or the suction pressure cannot be pumped down to the designed value, and the compressor will run for abnormally long intervals or continuously. You may get a rapid buildup of suction (crankcase) pressure during an off cycle. This causes the compressor to start after a very short off period and indicates leaking discharge valves.

If the refrigeration plant is not operating satisfactorily, you should first shift the compressors and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, the trouble is in the compressor and not in the system.

To test the compressor discharge valves, pump down the compressor to 2 psig. Then stop the compressor and quickly close the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 pounds in a minute and the crankcase suction pressure rises, this is evidence of compressor discharge valve leakage. If you must remove the discharge valves with the compressor pumped down, open the connection to the discharge pressure gauge to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate. Be careful not to damage the gaskets.

If the discharge valves are defective, replace the entire discharge valve assembly. Any attempt to repair them would probably involve relapping and would require highly specialized equipment. Except in an emergency, such repair should never be undertaken aboard ship.

The compressor internal suction valves may be checked for leakage as follows:

1. Start the compressor by using the manual control switch on the motor controller.
2. Close the suction line stop valve gradually, to prevent violent foaming of the compressor crankcase lubricating oil charge.
3. With this stop valve closed, pump a vacuum of approximately 20 inches Hg. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained

for the valves to wear in.

However, if any of the compressor suction valves are defective, pump down the compressor, open it, and inspect the valves. Replace defective valves or pistons with spare assemblies.

Crankcase Seal Repairs

There are several types of crankshaft seals, depending on the manufacturer. On reciprocating compressors, the crankshaft extends through the compressor housing to provide a mount for the pulley wheel or flexible coupling. At this point, the shaft must be sealed to prevent leakage of lubricating oil and refrigerant. The crankshaft seal is bathed in lubricating oil at a pressure equal to the suction pressure of the refrigerant. The first indication of crankshaft seal failure is excessive oil leaking at the shaft.

When the seal must be replaced or when it shows signs of abnormal wear or damage to the running surfaces, a definite reason can be found for the abnormal conditions. Make an inspection to locate and correct the trouble or the failure will recur.

Seal failure is very often caused by faulty lubrication, usually because of the condition of the crankcase oil. A dirty or broken oil seal is generally caused by one or both of the following conditions:

1. Dirt or foreign material is in the system or system piping. Dirt frequently enters the system at the time of installation. After a period of operation, foreign material will always accumulate in the compressor crankcase, tending to concentrate in the oil chamber surrounding the shaft seal. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal.
2. Moisture is frequently the cause of an acid condition of the lubricating oil. Oil in this condition will not provide satisfactory lubrication and will promote failure of the compressor parts. If moisture is suspected, use a refrigerant dehydrator when the compressor is put into operation. Anytime foreign material is found in the lubricating oil, thoroughly clean the entire system (piping, valves, and strainers).

If the seal is broken to the extent that it permits excessive oil leakage, do not attempt to pump the refrigerant out of the compressor. If you do, air containing moisture will be drawn into the system through the damaged seal. Moisture entering the refrigerant system may cause expansion valves to freeze. This can cause acid formation and other problems. If oil is leaking excessively, close the compressor suction and discharge valves and relieve the pressure to the atmosphere by loosening a connection on the compressor discharge gauge line.

Next, drain the oil from the compressor crankcase. Since the oil contains refrigerant, it will foam while being drained. Leave open the oil drain valve or plug while you are working on the seal. This ensures that refrigerant escaping from the oil remaining in the crankcase will not build up pressure and blow out the seal while it is being removed.

Remove the compressor flywheel (or coupling) and carefully remove the shaft seal assembly. If the assembly cannot be readily removed, build up a slight pressure in the compressor crankcase. To do this, slightly open the compressor suction valve and take the necessary precautions to support the seal to prevent it from being blown from the compressor and damaged.

INSTALLING SHAFT SEAL.—Clean and replace the entire seal assembly in accordance with the manufacturer's instructions.

Wipe the shaft clean with a linen or silk cloth; do not use a dirty or lint-bearing cloth. Unwrap the seal, being careful not to touch the bearing surfaces with your hands. Rinse the seal in an approved solvent and allow it to air-dry. (Do not wipe the seal dry.) Dip the seal in clean refrigerant oil. Follow the instructions found in the manufacturer's technical manual to insert the assembly. Bolt the seal cover in place and tighten the bolts evenly. Replace the flywheel and belts or coupling and check and correct the motor and compressor shaft alignment. Test the unit for leaks by opening the suction and discharge valves and using a halide leak detector.

Evacuating the Compressor

Whenever repairs to a compressor are of such a nature that any appreciable amount of air enters the unit, the compressor should be evacuated after

assembly is completed and before it is ready for operation. The proper procedure is as follows:

1. Disconnect a connection in the compressor discharge gauge line between the discharge line stop valve and the compressor.
2. Start the compressor and let it run until the greatest possible vacuum is obtained.
3. Stop the compressor and immediately open the suction stop valve slightly. This will blow refrigerant through the compressor valves and purge the air above the discharge valves through the open gauge line.
4. Close the discharge gauge line and open the discharge line stop valve.
5. Remove all oil from the exterior of the compressor. Test the compressor joints for leakage using the halide leak detector.

Cleaning Suction Strainers

When putting a new unit into operation, you should clean the suction strainers after a few hours of operation. Refrigerants have a solvent action and will loosen any foreign matter in the system. This foreign matter will eventually reach the suction strainers. After a few days of operation, the strainers will need another cleaning. Inspect them frequently during the first few weeks of plant operation and clean as necessary.

The suction strainers are located in the compressor housing or in the suction piping. The procedure for cleaning the strainers is as follows:

1. Pump down the compressor.
2. Remove the strainer and inspect it for foreign matter.
3. To clean the strainer screen, dip it in an approved solvent and allow it to dry.
4. Replace the strainer and evacuate the air from the compressor.
5. Test the housing for leaks by wiping up all oil and then using a halide leak detector.

Maintenance Precautions

Sometimes a compressor cannot be pumped down and is damaged to the extent that it has to be opened for repairs. If so, you should first close the suction and discharge valves and then allow all refrigerant in the compressor to vent to the atmosphere through a gauge line.

When you must remove, replace, or repair internal parts of the compressor, observe the following precautions:

1. Carefully disassemble and remove parts, noting the correct relative position so that errors will not be made when reassembling.
2. Inspect all those parts that become accessible because of the removal of other parts requiring repair or replacement.
3. Make certain that all parts and surfaces are free of dirt and moisture.
4. Apply clean compressor oil freely to all bearing and rubbing surfaces of parts being replaced or reinstalled.
5. If the compressor is not equipped with an oil pump, make certain that the oil dipper on the lower connecting rod is in the correct position for dipping oil when the unit is in operation.
6. Position the ends of the piston rings so that alternate joints are on the opposite side of the piston.
7. Take care not to score gasket surfaces.
8. Renew all gaskets.
9. Clean the crankcase and renew the oil.

CONDENSERS

The compressor discharge line terminates at the refrigerant condenser. In shipboard installations, these condensers are usually of the multipass shell-and-tube type, with water circulating through the tubes. The tubes are expanded into grooved holes in the tube sheet to make a tight joint between the shell and the circulating water. Refrigerant vapor is admitted to the shell and condenses on the outer surfaces of the tubes.

Any air or noncondensable gases that may accidentally enter the refrigeration system will be drawn through the piping and eventually discharged into the condenser with the refrigerant. The air or noncondensable gases accumulated in the condenser are lighter than the refrigerant gas. They will rise to the top of the condenser when the plant is shut down. A purge valve, for purging the refrigeration system (when necessary), is installed at the top of the condenser or at a high point in the compressor discharge line.

CLEANING CONDENSER TUBES

To clean the condenser tubes properly, first drain the cooling water from the condenser. Then

condenser heads. Be careful not to damage the gaskets between the tube sheet and the waterside of the condenser heads. Inspect tubes as often as practical and clean them as necessary, using an approved method. Use rubber plugs and an air lance or a water lance to remove foreign deposits. You must keep the tube surfaces clear of particles of foreign matter. However, take care not to destroy the thin protective coating on the inner surfaces of the tubes. If the tubes become badly corroded, replace them. This avoids the possibility of losing the charge and admitting salt water to the system.

CLEANING AIR-COOLED CONDENSERS

Although the large plants are equipped with water-cooled condensers, auxiliary units are commonly provided with air-cooled condensers. The use of air-cooled condensers eliminates the necessity for circulating water pumps and piping.

Keep the exterior surface of the tubes and fins on an air-cooled condenser free of dirt or any matter that might obstruct heat flow and air circulation. The finned surface should be brushed clean with a stiff bristle brush as often as necessary. Low-pressure air will prove very useful in removing dirt from condensers in hard-to-reach places. When installations are exposed to salt spray and rain through open doors or hatches, care should be taken to minimize corrosion of the exterior surfaces.

TESTING FOR LEAKS

To prevent serious loss of refrigerant through leaky condenser tubes, test the condenser for leakage by following the PMS.

To test for leaky condenser tubes, drain the waterside of the condenser. Then insert the exploring tube of the leak detector through one of the drain plug openings. If this test indicates that Freon gas is present, you can find the exact location of the leak as follows:

1. Remove the condenser heads.
2. Clean and dry the tube sheets and the ends of the tubes.
3. Check both ends of each tube with a leak detector. Mark any tubes that show leakage. If you cannot determine that the tube is leaking internally or around the tube sheet joint, plug the suspected tube and again check around the tube to isolate the suspected area.
4. To locate or isolate very small leaks in the condenser tubes, hold the exploring tube at one end of the condenser tube for about 10 seconds to draw fresh air through the tube. Repeat this procedure with all the tubes in the condenser. Allow the condenser tubes to remain plugged for 4 to 6 hours; then, remove the plugs one at a time and check each tube for leakage. If a leaky tube is detected, replace the plug immediately to reduce the amount of refrigerant escaping. Make appropriate repairs or mark and plug all leaky tubes for later repairs.

RETUBING CONDENSERS

The general procedures for retubing condensers are in chapter 5 of this training manual. You can find further information in chapter 9590 of *Naval Ships' Technical Manual*. When retubing a specific condenser, follow the procedures in the manufacturer's technical manual.

THERMOSTATIC EXPANSION VALVES

The thermostatic expansion valve is essentially a reducing valve between the high-pressure side and the low-pressure side of the system. The valve is designed to proportion the rate at which the refrigerant enters the cooling coil to the rate of evaporation of the liquid refrigerant in the coil; the amount depends, of course, on the amount of heat being removed from the refrigerated space.

When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble can usually be traced to moisture or dirt collecting at the valve seat and orifice.

TESTING AND ADJUSTMENT

By means of a gear and screw arrangement, the thermostatic expansion valves used in most shipboard systems can be adjusted to maintain a superheat ranging approximately from 4 °F to

12 °F at the cooling coil outlet. The proper superheat adjustment varies with the design and service operating conditions of the valve and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet and decreased pressure has the opposite effect.

Some thermostatic expansion valves have a fixed (nonadjustable) superheat. These valves are used in equipment or systems where the piping configuration and evaporating conditions are constant, primarily in self-contained equipment.

If expansion valves are adjusted to give a high superheat at the coil outlet or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. With an insufficient amount of refrigerant, the coil will be "starved" and will operate at a reduced capacity. Also, the velocity of the refrigerant through the coil may not be adequate to carry oil through the coil. This robs the compressor crankcase and provides a condition where slugs of lubricating oil may be drawn back into the compressor. If the expansion valve is adjusted for too low a degree of superheat or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. Should the liquid refrigerant collect at a low point in the suction line or coil and be drawn back into the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air-conditioning and water-cooling plants (high-temperature installations) normally are adjusted for higher superheat than the expansion valves for cold storage refrigeration and ship's service store equipment (low-temperature installations).

You may not be able to adjust expansion valves to the desired settings, or you may suspect that the expansion valve assembly is defective and requires replacement. In either case, you should make appropriate tests. Normally you should first be sure that the liquid strainers are clean, that the solenoid valves are operative, and that the system is sufficiently charged with refrigerant.

The major equipment required for expansion valve tests is as follows:

- A service drum of R-12 or a supply of clean, dry air at 70 to 100 psig. The service drum is used to supply gas under pressure. The gas does not have to be the same as that used in the thermal element of the valve being tested.
- A high-pressure and a low-pressure gauge. The low-pressure gauge should be accurate and in good condition so that the pointer does not have any appreciable lost motion. The high-pressure gauge, while not absolutely necessary, will be useful in showing the pressure on the inlet side of the valve. Refrigeration plants are provided with suitable replacement and test pressure gauges.

The procedure for testing is as follows:

1. Connect the valve inlet to the gas supply with the high-pressure gauge attached to indicate the gas pressure to the valve and with the low-pressure gauge loosely connected to the expansion valve outlet. The low-pressure gauge is connected loosely to provide a small amount of leakage through the connection.
2. Insert the expansion valve thermal element in a bath of crushed ice. Do not attempt to perform this test with a container full of water in which a small amount of crushed ice is floating.
3. Open the valve on the service drum or in the air supply line. Make certain that the gas supply is sufficient to build up the pressure to at least 70 psi on the high-pressure gauge connected in the line to the valve inlet.
4. The expansion valve can now be adjusted. If you want to adjust for 10 °F superheat, the pressure on the outlet gauge should be 22.5 psig. This is equivalent to an R-12 evaporating temperature of 22 °F. Since the ice maintains the bulb at 32 °F, the valve adjustment is for 10 °F superheat (difference between 32 and 22). For a 5 °F superheat adjustment, the valve should be adjusted to give a pressure of approximately 26.1 psig. There must be a small amount of leakage through the low-pressure gauge connection while this adjustment is being made.
5. To determine if the valve operates smoothly, tap the valve body lightly with a small weight. The low-pressure gauge needle should not jump more than 1 psi.
6. Now tighten the low-pressure gauge connection to stop the leakage at the joint and determine if the expansion valve seats tightly. With the valve in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve, the pressure will build up rapidly until it equals the inlet pressure. With externally equalized valves, the equalizer line must be connected to the piping from the valve outlet to the test gauge to obtain an accurate superheat setting.

7. Again loosen the gauge to permit leakage at the gauge connection. Remove the thermal element, or control bulb, from the crushed ice. Warm it with your hands or place it in water that is at room temperature. When this is done, the pressure should increase rapidly, showing that the power element has not lost its charge. If there is no increase in pressure, the power element is dead.

8. With high pressure showing on both gauges as outlined above, the valve can be tested to determine if the body joints or the bellows leak. This can be done by using a halide leak detector. When you perform this test, it is important that the body of the valve have a fairly high pressure applied to it. In addition, the gauges and other fittings should be made up tightly at the joints to eliminate leakage at these points.

REPLACEMENT OF VALVES

If the expansion valve is defective, it must be replaced. Most valves used on naval ships have replaceable assemblies. It is possible to replace a faulty power element or some other part of the valve without having to replace the entire assembly. When replacement of an expansion valve is necessary, you must replace the unit with a valve of the same capacity and type.

ADDITIONAL SYSTEM MAINTENANCE

In addition to the maintenance of the components described above, other parts of the system will need periodic maintenance to keep the plant operating properly.

Vibration may cause leakage in the piping system, allowing air and moisture to be drawn in or a loss of the refrigerant charge. If this happens, the plant operation will become erratic and inefficient, and the cause of trouble must be corrected.

CHARGING THE SYSTEM

Information concerning the charging of refrigeration systems may be found in chapter 9590 of *Naval Ships' Technical Manual*. The amount of refrigerant charge must be sufficient to maintain a liquid seal between the condensing and evaporating sides of the system. Under normal operating conditions, when the compressor stops, the receiver of a properly charged system is about 85-percent full of refrigerant. The proper charge for a specific system or unit can be found in the manufacturer's technical manual or on the ship's blueprints.

A refrigeration system should not be charged if it has leaks or if you have reason to believe the system has a leak. The leaks must be found and corrected. Immediately following—or during—the process of charging, the system should be carefully checked for leaks.

A refrigeration system must have an adequate charge of refrigerant at all times; otherwise, its efficiency and capacity will be impaired.

PURGING THE SYSTEM

To determine if the system contains noncondensable gases, operate the system for 30 minutes. Stop the compressor for 10 to 15 minutes, leaving all valves in their normal position. Observe the pressure and temperature as indicated on the high-pressure gauge. Read the thermometer in the liquid line, or read the temperature of the cooling water discharge from the condenser. Compare it with the temperature conversion figures shown on the discharge pressure gauge. If the temperature of the liquid leaving the receiver is more than 5 °F lower than the temperature corresponding to the discharge pressure, the system should be purged. Pump the system down and secure the compressor; then open the purge valve on the condenser. Purge very slowly, at intervals, until the air is expelled from the system and the temperature difference drops below 5 °F.

CLEANING LIQUID LINE STRAINERS

Where a liquid line strainer is installed, it should be cleaned at the same intervals as the suction strainer. If a liquid line strainer becomes clogged to the extent that it needs cleaning, a loss of refrigeration effect will take place. The tubing on the outlet side of the strainer will be much colder than the tubing on the inlet side.

To clean the liquid line strainer, secure the receiver outlet valve and wait a few minutes to allow any liquid in the strainer to flow to the cooling coils. Then close the strainer outlet valve and very carefully loosen the cap that is bolted to the strainer body. (Use goggles to protect your eyes.) When all the pressure is bled out of the strainer, remove the cap and lift out the strainer screen. Clean the strainer screen, using an approved solvent and a small brush. Reassemble the spring

and screen in the strainer body; then replace the strainer cap loosely. Purge the air out of the strainer by blowing refrigerant through it; then tighten the cap. After the assembly is complete, test the unit for leaks.

CLEANING OIL FILTERS AND STRAINERS

Compressors arranged for forced feed lubrication are provided with lubricating oil strainers in the suction line of the lube-oil pump. An oil filter may be installed in the pump discharge line. A gradual decrease in lubricating oil pressure indicates that these units need cleaning. This cleaning may be accomplished in much the same manner as described for cleaning suction strainers.

When cleaning is necessary, the lubricating oil in the crankcase should be drained from the compressor. A new charge of oil, equal to the amount drained, should be added before restarting the unit. When the compressor is put back into operation, the lube-oil pressure should be adjusted to the proper setting by adjustment of the oil pressure regulator.

MAINTAINING COOLING COILS

Cooling coils should be inspected regularly and cleaned as required. The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Excessive buildup of frost on the cooling coils will result in reduced capacity of the plant, low compressor suction pressure, and a tendency for the compressor to short-cycle. The maximum time interval between defrosting depends on many factors. Some of these are refrigerant evaporating temperature, condition of door gaskets, moisture content of supplies placed in boxes, frequency of opening doors, and atmospheric humidity.

You should always defrost the cooling coils before the frost thickness reaches three-sixteenths of an inch. When defrosting, ensure that the frost is not scraped or broken off. This may cause damage to the coils.

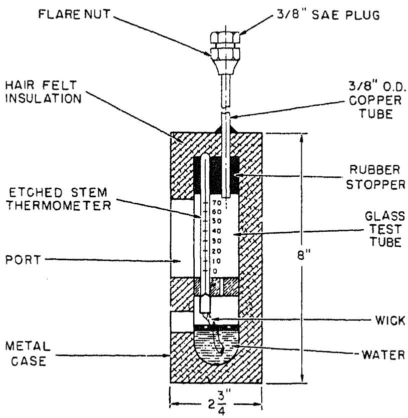
EVACUATING AND DEHYDRATING THE SYSTEM

Where moisture accumulation must be corrected, the system should first be cleared of refrigerant and air. The time required for these processes will depend upon the size of the system and the amount of moisture present. It is good engineering practice to circulate heated air through a large dehydrator system for several hours, or as long as the dehydrator drying agent remains effective, before proceeding with the evacuation process. If possible, the dehydrated air should be heated to about 240°F.

Large dehydrators, suitable for preliminary dehydration of refrigeration systems, are usually available at naval shipyards and on board tenders and repair ships.

After the preliminary dehydration, the remaining moisture is evacuated by means of a two-stage, high-efficiency vacuum pump having a vacuum indicator. (These vacuum pumps are available on board tenders and repair ships.)

The vacuum indicator shown in figure 8-4 consists of an insulated test tube containing a wet bulb thermometer with its wick immersed in distilled water. The indicator is connected in the vacuum



CONVERSION TEMPERATURE °F TO ABSOLUTE PRESSURE INCHES MERCURY

TEMPERATURE °F	ABSOLUTE PRESSURE INCHES MERCURY
60	0.521
55	0.436
50	0 362
45	0.300
40	0.248
35	0.204
32	0.181

96.32

Figure 8-4.—Dehydrator vacuum indicator.

vacuum pump is connected to the refrigeration system. The refrigerant circuit should be closed to the atmosphere and the charging connection opened to the vacuum pump.

A two-stage pump is started for operation in PARALLEL so that maximum displacement may be obtained during the initial pump-down stages. When the indicator shows a temperature of about 55 °F (0.43 inch Hg, absolute), the pumps are placed in SERIES operation (where the discharge from the first step enters the suction of the second step pump). The dehydration process will be reflected in the temperature drop of the vacuum indicator as shown in figure 8-5. Readings will initially reflect ambient temperatures, then show rapidly falling temperatures until the water in the system starts to boil.

When most of the evaporated moisture has been evacuated from the system, the indicator will show a decrease in temperature. When the temperature reaches 35 °F (0.2 inch Hg, absolute), dry air should be admitted through a chemical dehydrator into the system at a point farthest from the pump. Continue operating the pump; the dry air will mix with and dilute any remaining moisture. Secure the opening that feeds the dry air into the system. Continue evacuating the system until the indicator again shows a temperature of 35 °F. At this time, the dehydration process is complete. Close the valves and disconnect the vacuum pump.

Sometimes obtaining a temperature as low as 35 °F in the vacuum indicator will be impossible.

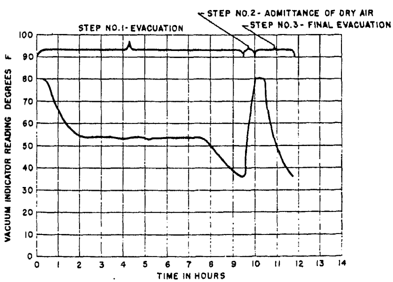


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Figure 8-5.—Vacuum indicator readings plotted during dehydration.

corrective procedures to take are as follows:

- Excess moisture in the system. The dehydration procedure should be conducted for longer periods.

- Absorbed refrigerant in the lubricating oil contained in the compressor crankcase. Remove the lubricating oil from the crankcase before proceeding with the dehydration process.

- Leakage of air into the system. The leak must be found and stopped. You must then repeat the procedure required for detecting leaks in the system.

- Inefficient vacuum pump or defective vacuum indicator. The defective unit(s) should be repaired or replaced.

Immediately after each period of use or after the system has been opened for repairs, the drying agent in the dehydrator should be replaced. If a replacement cartridge is not available, the drying agent can be reactivated and used until a replacement is available.

Reactivation is accomplished by removing the drying agent and heating it for 12 hours at a temperature of 300 °F to bake out the moisture. The drying agent may be placed in an oven, or a stream of hot air may be circulated through the cartridge. These methods are satisfactory for reactivating commonly used dehydrating agents such as activated alumina and silica gel. Where special drying agents are employed, the specific instructions furnished by the manufacturer should be followed to reactivate the agents.

After reactivation, the drying agent should be replaced in the dehydrator shell and sealed as quickly as possible. This prevents absorption of atmospheric moisture. When the drying agent becomes fouled or saturated with lubricating oil, it must be replaced by a fresh charge, or dehydrator cartridge, taken from a sealed container.

Remember that the dehydrators permanently installed in refrigeration systems of naval ships are designed to remove only the minute quantities of moisture unavoidably introduced in the system. Extreme care must be taken to prevent moisture or moisture-laden air from entering the system.

CLEANING THE SYSTEM

Systems may accumulate dirt and scale as a result of improper techniques used during repair or installation of the system. If such dirt is excessive and a tank-type cleaner is available, connect the cleaner to the compressor suction strainer. Where such a cleaner is not available, a hard, wool felt filter about five-sixteenths inch thick, should be inserted into the suction strainer screen. The plant should be operated, with an operator in attendance, for at least 36 hours or until the system is cleaned, depending upon the size and condition of the plant.

AIR-CONDITIONING CONTROL

Most of the information presented to this point applies to the refrigeration side of a system, whether it is used for a refrigeration plant or for air conditioning. The compressor controls for both types of systems are nearly identical; however, the devices used to control space temperatures differ. The two-position dual control, called 2PD, is used for the automatic control of most shipboard air-conditioning systems.

TWO-POSITION DUAL CONTROL (2PD)

This control may be used on three types of systems:

1. Systems employing a simple thermostatically controlled single-pole switch to control flow of refrigerant to the cooling coil.
2. Systems using reheaters, employing a thermostatic element actuating two interlocked switches.
3. Systems using reheaters in the same manner as those in item 2, with control of humidity added where specified.

The type 1 system, because of its simplicity, requires little explanation. The thermostat consists of a temperature-sensing element actuating a single-pole, single-throw switch. It opens and closes a magnetic valve to start and stop the flow of refrigerant-chilled water or commercial refrigerant. This type of control is similar to thermostatic control for the refrigeration plant. Although the type 1 system requires single-pole thermostats, the 2PD used in types 2 and 3 systems can be used. The cooling switch would then be connected in the normal manner with the heating switch inoperative.

The type 2 system is most commonly used because of past experiences and present efforts to make living and working spaces more habitable, also because of the rapid development of various types of weapons systems that require cooling. These systems often use a common cooling coil serving several different spaces. Assume three spaces are being cooled by a common coil. Since the load changes seldom occur simultaneously, electric or steam reheaters are installed in the cooling air ducts. The cooling thermostats of the various spaces are connected in parallel so that any one may open the cooling coil valve.

Suppose space B in figure 8-6 has a load change and spaces A and C do not. With the coil operating to take care of space B, these spaces would become too cold for comfort. To prevent this condition, the thermostat would close the heating switch and energize the reheaters for spaces A and C.

The type 3 system is identical to the type 2 system, except that a humidistat is wired in parallel with the thermostatic heating switch. This type of system is used mostly in weapons and electronic spaces. The humidistat is set for the relative humidity condition desired. In most installations, it is only necessary to prevent the humidity from exceeding 55 percent. Where the humidistat is installed, an increase in temperature beyond the thermostat setting will close the thermostat cooling switch. An increase in relative humidity beyond the humidistat setting will close the heating switch and energize the reheaters.

MAINTENANCE

Proper attention to the planned maintenance system often exposes developing troubles in time to take corrective action. Since most breakdowns occur at the most inopportune times, periodic checks and maintenance will prove to be worthwhile to avoid malfunctions.

The two-position control system can easily be checked out in a reasonably short time. The checkout should be made at least every 3 months or more often if necessary. Inspection and checks should be made at the beginning of, and midway through, the cooling season, and at the same times during the heating season.

Sensing elements should be inspected and any dust accumulations removed. Thermostatic sensing elements may have dust and dirt removed

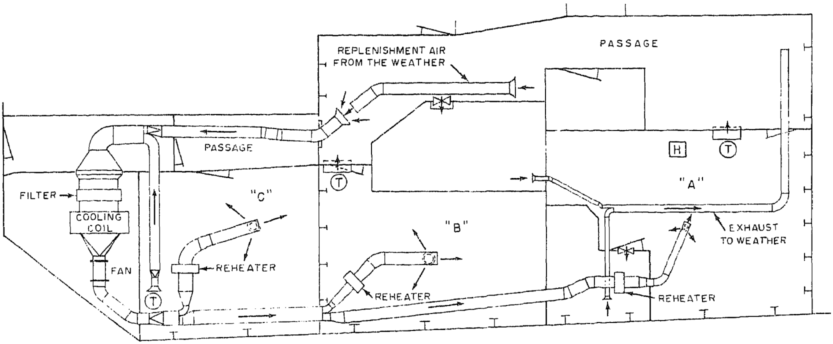

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Figure 8-6.—Typical air conditioning system.

with a soft brush. Sensing elements in humidistats must be blown off gently with air so as not to damage the element.

Magnetic valves should be checked for operation. Be sure that they open and close completely.

Set points of the thermostats and humidistats should be checked with a calibrated thermometer and a reliable humidity indicator.

When servicing the two-position control system, look for three possible sources of trouble.

- The sensing element and its associated mechanism

- The magnetic valves that control the flow of refrigerant

- The wiring system that connects the sensing elements to the solenoids of the magnetic valves and the controller of the electric heaters

DETECTING AND CORRECTING PROBLEMS

A number of symptoms indicate faulty operation of refrigeration and air-conditioning plants. Figure 8-7 lists some of the problems along with possible causes and corrective measures. Figure 8-8 also lists some of the problems, causes, and corrective measures and includes recommended test procedures that may be used to isolate the problems.

SAFETY PRECAUTIONS USED WHEN HANDLING REFRIGERANTS

The following safety precautions are the minimum required when you are using refrigerants:

1. Two people shall be present at all times while refrigerant is being charged into a refrigeration system. NEVER leave the area unattended while charging is in progress.
2. Ensure that ventilation in the space is adequate to keep the concentration of refrigerant below 1,000 parts per million. If necessary, use portable blowers.
3. If refrigerant is being charged into or being removed from a system, prohibit all nonessential personnel from being in or entering the space while the refrigerant is being transferred.
4. Locate an emergency self-contained breathing apparatus for each person in the space to permit safe evacuation in the event of a large accidental leak.
5. If you are entering, or you are in, a space when refrigerant may be present in the atmosphere, leave the space immediately if:

- You smell something that is unusual.

- You feel light-headed.

Trouble	Possible Cause	Corrective Measure
High condensing pressure.	Air on non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser.	Increase quantity of water.
	Condenser tubes clogged or scaled.	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
Low condensing pressure.	Too much water flowing through condenser.	Reduce quantity of water.
	Water too cold.	Reduce quantity of water.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve.	Remove head, examine valves. Replace any found defective.
High suction pressure.	Overfeeding of expansion valve.	Regulate expansion valve, check bulb attachment.
	Leaky suction valve.	Remove head, examine valve and replace if worn.
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine and clean screens.
	Insufficient refrigerant in system.	Check for refrigerant storage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Expansion valve power element dead or weak.	Replace expansion valve power element.

54.299

Figure 8-7.—Trouble diagnosis chart.

Trouble	Possible Cause	Corrective Measure
Compressor short cycles on low pressure control.	Low refrigerant charge.	Locate and repair leaks. Charge refrigerant.
	Thermal expansion valve not feeding properly. (a) Dirty strainers. (b) Moisture frozen in orifice or orifice plugged with dirt. (c) Power element dead or weak.	Adjust, repair or replace thermal expansion valve. (a) Clean strainers. (b) Remove moisture or dirt (Use system dehydrator). (c) Replace power element.
	Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost.	Remove restriction. Check water flow. Clean coils or tubes.
	Defective low pressure control switch.	Repair or replace low pressure control switch.
Compressor runs continuously.	Shortage of refrigerant.	Repair leak and recharge system.
	Leaking discharge valves.	Replace discharge valves.
Compressor short cycles on high pressure control switch.	Insufficient water flowing through condenser, clogged condenser.	Determine if water has been turned off. Check for scaled or fouled condenser.
	Defective high pressure control switch.	Repair or replace high pressure control switch.
Compressor will not run.	Seized compressor.	Repair or replace compressor.
	Cut-in point of low pressure control switch too high.	Set L.P. control switch to cut-in at correct pressure.
	High pressure control switch does not cut-in. 1. Defective switch. 2. Electric power cut off. 3. Service or disconnect switch open.	Check discharge pressure and reset H.P. control switch. 1. Repair or replace switch. 2. Check power supply. 3. Close switches.

54.299.2

Figure 8-7.—Trouble diagnosis chart—Continued.

Trouble	Possible Cause	Corrective Measure
Compressor will not run. (Cont'd)	4. Fuses blown.	4. Test fuses and renew if necessary.
	5. Over-load relays tripped.	5. Re-set relays and find cause of overload.
	6. Low voltage.	6. Check voltage (should be within 10 percent of nameplate rating).
	7. Electrical motor in trouble.	7. Repair or replace motor.
	8. Trouble in starting switch or control circuit.	8. Close switch manually to test power supply. If OK check control circuit including temperature and pressure controls.
	9. Compressor motor stopped by oil pressure differential switch.	9. Check oil level in crankcase. Check oil pump pressure.
Sudden loss of oil from crankcase.	Liquid refrigerant slugging back to compressor crank case.	Adjust or replace expansion valve.
Capacity reduction system fails to unload cylinders.	Hand operating stem of capacity control valve not turned to automatic position.	Set hand operating stem to automatic position.
Compressor continues to operate at full or partial load.	Pressure regulating valve not opening.	Adjust or repair pressure regulating valve.
Capacity reduction system fails to load cylinders.	Broken or leaking oil tube between pump and power element.	Repair leak.
Compressor continues to operate unloaded.	Pressure regulating valve not closing.	Adjust or repair pressure regulating valve.

54.299.3

Figure 8-7.—Trouble diagnosis chart—Continued.

TROUBLE	POSSIBLE CAUSE	TEST	REMEDY
Space temperature higher than thermostat setting	Bad location of thermostat	Carefully read temperature at the sensing element	Relocate thermostat to a place more representative of average space temperature
	Thermostat out of adjustment or sticking	Calibrate with good thermometer	Clean, adjust, or replace the thermostat
	Cooling coil magnetic valve not opening	Solenoid Valve Valve sticking	Replace solenoid coil. Clean valve or adjust pilots.
Space temperature lower than thermostat setting	Bad location of thermostat (this will also affect cooling)	Test with reliable thermometer at location	Move thermostat to a better location.
	Cooling coil magnetic valve stuck in open position	Stuck valve	Disassemble and clean.
	Heating coil magnetic valve stuck or bad solenoid	Test solenoid. Test valve.	Replace solenoid coil. Clean the valve.
Thermostat or humidistat time constant too long, causing wide deviation from set point	Sensing element fouled with lint and dirt	Examine	Clean.
Electric heater does not cut out	Controller contacts stuck	Use test lamp to determine	Replace contacts, springs or other parts as found defective.
Electric heater does not cut in	Overheat protection not reset or defective	Place test lamp across	Repair or replace.

121.38

Figure 8-8.—Trouble diagnosis chart.

- You feel giddy.
- You experience shortness of breath.
- You feel a tingling sensation in your fingers or toes.
- You suddenly start to feel warm.
- You experience rapid heartbeat.

6. Before using refrigerant, ensure that all hot work in the space is suspended.

7. Use chemical safety goggles or a full face shield while handling refrigerant.

8. Exercise care to ensure that liquid refrigerant does not come in contact with your skin.

9. Where available, use a halide monitor with an alarm to continuously monitor the atmosphere in the space where refrigerant is used.

10. Post a caution sign in the area to read as follows:

CAUTION

NO OPEN FLAME, SMOKING, OR WELDING. DO NOT ENTER WITHOUT TESTING THE AIR FOR REFRIGERANT.

11. Establish and document emergency rescue procedures to ensure all personnel can be safely removed from potentially hazardous exposures.

CHAPTER 9

AUXILIARY EQUIPMENT

This chapter provides general information on a variety of equipment that is not directly related to the propulsion plant. Some of the equipment that will be discussed includes the steering gear, cargo or weight-handling equipment, hydraulic systems, and landing and galley equipment.

Although the Machinist Mates are not usually the operators of the above mentioned equipment, you, as the MM1 or MMC will be responsible for the repairs, replacements, or adjustments with the exception of the electrical work.

For any additional information on auxiliary equipment, refer to the manufacturer's technical manual or the *Naval Ships' Technical Manual.*

STEERING GEAR

Most modern naval vessels have electrohydraulic steering gear. This type of steering gear was developed because of the heavy power requirements for steering gear on large high-speed ships.

You will be responsible for the maintenance and repair of the pumps and components of the hydraulic system. Therefore, you should familiarize yourself with this type of equipment. Your best source of information is the manufacturer's instruction book.

GENERAL DESCRIPTION

In electrohydraulic steering gear, the rudder is usually moved by hydraulic rams operating in cylinders connected hydraulically to variable delivery pumps. The pumps are driven by continuously running electric motors. The direction and rate of rudder travel are controlled by changing the position of the tilting block in the hydraulic pump.

On most large naval ships, two complete power units are provided for each ram. In such dual installations both motors and pumps may be operated at once. However, only one pump is normally connected to the ram at any given time. Dual power units provide an added safety factor; however, both power units should be run at the same time only long enough to check out and warm up the system.

CONTROL SYSTEMS

The remote control of steering gears on most Navy ships is done electrically by means of an alternating-current synchronous transmission system. The power-type system consists of interchangeable receiving and transmitting units. When the transmitter rotor is turned, the receiver rotor turns in synch; that is, at the same speed and in the same direction. The transmitters are located in the steering room and in the pilot house. They are mechanically connected through gearing to the steering wheels. The transmitters at each of the control stations are electrically connected to the receivers in the steering room. Generally, the circuits connecting the transmitters to the receivers are run in duplicate cables—one running along the port side of the ship and one running along the starboard side. Indicator lights show the cable, transmitter-receiver, and power sources in use.

Any apparent deficiencies in the electrical steering control system should be investigated and reported immediately. Some examples are sluggishness during operation and incorrect setting at rudder limit stops or control linkage.

EMERGENCY STEERING GEAR

Emergency hand-driven steering gear is provided on all combatant and auxiliary ships that have electrohydraulic steering gear. This steering gear consists of a small hydraulic pump, associate shuttle valves, piping, relief valves, and fittings. This equipment is located in the steering room. The piping from the hand pump is connected to the drainlines to eliminate the need for an additional high-pressure cutout valve. Manual positioning of the transfer valve isolates the rams

from the main pumps to prevent motoring of the main power units. The pump is hand cranked and usually set at a reduced stroke for hand steering. The pump operates in either direction of rotation, allowing for rudder positioning.

Some large combatant ships have separate emergency hydraulic units for each steering gear that are driven by electric motors. These units can operate the ram cylinders when the steering units are submerged. A single hand wheel controls the flow of oil for the rams and operates the rudder at a greatly reduced rate.

ANCHOR WINDLASSES

A windlass is used intermittently and for relatively short periods of time. It must handle the required load under extremely severe conditions. To prevent deterioration and to provide dependable operation whenever required, maintenance and adjustment must be continued during the periods when the machinery is not in use.

Windlass brakes (electric and hand brake) must be maintained in satisfactory condition if they are to perform their function properly. Because of wear and compression of brake linings, the clearance between the brake drum and band will increase after a windlass has been in operation. Means of adjustment are provided on all windlass brakes. Maladjustment of a windlass brake could result in the loss of the anchor and chain. Therefore, you should become familiar with maintenance procedures.

Lubrication instructions should be carefully followed. If a windlass has been idle for some time, lubrication of the equipment should be accomplished before operation is attempted. After a windlass has been used, the equipment should be lubricated to protect finished surfaces from corrosion.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. These tolerances are to be maintained and unnecessary wear prevented. Every precaution possible must be taken to prevent the entry of dirt and other abrasive material. When the system is replenished or refilled, only clean oil should be used and the oil should be strained as it is poured into the tank. If a hydraulic transmission has been disassembled,

their interiors should be cleaned to remove any scale, sand, or other foreign matter.

WINCHES AND CRANES

In several respects, the maintenance of a winch is similar to that of a windlass. The drum brake on winches and cranes will normally see very little wear since it is normally applied when the load has stopped moving. The electric or hydraulic brake mounted on the input shaft of the gear box of the winch or crane receives essentially all the wear. It should be inspected regularly and repaired when necessary. Steps should be taken to prevent oil or grease from accumulating on the brakes. The operation of brake-actuating mechanisms, latches, and pawls should be checked periodically.

The sliding parts of positive clutches must be properly lubricated, and the locking device on the shifting gear should be checked to determine if it will hold under load. The oil of gear reduction units should be checked for proper amount and purity. Periodic inspections should be made of the pressure lubrication fittings normally installed on slow-moving parts. On installations that use hydraulic transmission, the pumps and lines are maintained in the same way as those of any other hydraulic system.

As with many other auxiliary units, winches and cranes may be driven by hydraulic transmissions, by electric motors, by diesel engines, or by hand. Maintenance should be accomplished in accordance with the planned maintenance system (PMS). In general, the maintenance of electrohydraulic cranes requires that the oil in the replenishing tanks be kept at the prescribed levels, and that the system be kept clean and free of air. The limit stop and other mechanical safety devices must be checked regularly for proper operation. When cranes are not in use, they should be secured in their stowed positions. All electric power to the crane controllers should be disconnected at the power distribution panel.

ELEVATORS

Carriers have two or more electrohydraulic elevators capable of handling airplanes between the flight and hangar decks at relatively high speed. You may not be called upon too frequently to maintain this type of machinery. If you are, you will find maintenance procedures similar to

Elevator cables and fittings should be inspected frequently, and the tension of the cables in each group kept equal. Frequent inspections ensure that (1) there is proper oil level in the pressure and exhaust tanks, (2) there is no excessive leakage in the sump leak-off connections, (3) the pistons seal properly in the hydraulic cylinders, and (4) the entire system is clean.

CONVEYORS

Two types of conveyors are used for shipboard handling; gravity and powered. Gravity-type conveyors should require little or no maintenance. The powered vertical conveyors, tray type, will require PMS.

Vertical conveyors consist of a drive system that includes a drive motor, clutch, speed reducer, motor brake, drive shafts with chain sprockets, and connecting roller chain. The conveying system consists of a chain sprocket and an endless roller chain connected to guide tracks that carry the trays. Each conveyor has operating controls and various safety devices.

Periodic tests and inspections are required to ensure accident-free conveyor operation. For further information, consult your manufacturer's technical manual and *Naval Ship's Technical Manual,* chapters 562 and 9830.

HYDRAULIC SYSTEMS

The overall efficiency of hydraulic installations used to control or drive auxiliary machinery is basically dependent upon size of installation, oil pressure, speed, and condition of the equipment. The care given the hydraulic components of the system is an important factor. Major repair of hydraulic gear, except for piping and fittings, is generally performed at a naval shipyard or by the manufacturer. Routine maintenance, keeping the oil clean, and maintaining proper fluid levels is the responsibility of the operator.

Hydraulic transmissions are sturdy, proven machines, inspected and tested with such care that casualties seldom occur except as a result of faulty assembly, installations, or maintenance. If a properly installed hydraulic system is operated regularly and maintained with proper care, it will retain its design characteristics of power, speed, and control, and the need for costly repair and replacement will seldom occur.

PIPING AND FITTINGS

Properly installed hydraulic piping and valves are seldom a source of trouble, except for leakage. Some leaks may become serious enough to cause a reduction in the efficiency of the unit. Frequent inspections should be made and necessary steps taken to eliminate leakage.

If leaks occur at a flanged joint in the line of a hydraulic system, tighten the flange bolts evenly, but not excessively. If the leaks persist, use the standby unit, if available. If not, secure the equipment while the gasket of the leaking flange is being replaced. Make certain that the flange surfaces are cleaned carefully before the gasket is applied. (NOTE: Fittings should not be tightened while the system is pressurized.)

Relief valves or shuttle valves of a hydraulic system may be sources of trouble. Loss of power may indicate a leaking relief valve. Shuttle valves may stick and fail to cut off. This condition is indicated when oil escapes from the high-pressure side of the line into the expansion tank or when the pressure control fails. When a shuttle valve fails to operate, the stop valves should be closed and the defective valve removed for repair. The seats of leaking relief valves should be reground.

FLUID SYSTEM

An inspection of an oil sample drawn from a hydraulic system may reveal the presence of metal particles, water, sludge, acidity, or other contaminants. If so, the system must be drained, flushed, and refilled in accordance with current applicable Navy procedures for the particular system. The presence of foreign particles in the hydraulic system indicates a possible component malfunction, which should be corrected prior to flushing the system.

Hydraulic fluid may be contaminated by use as the working fluid or as a flushing medium. It must not be used again, but should be disposed of according to prevailing instructions.

PUMPS AND MOTORS

An electric motor rotates the hydraulic pump. Oil under pressure is delivered from the pump to the hydraulic motor of the variable speed transmission through piping. The hydraulic motor rotates the individual unit or equipment through suitable reduction gearing. Whether the pumps and motors of hydraulic transmissions are of the axial or radial piston type, maintenance

procedures and operating principles are relatively the same. In general, maintenance information on other types of pumps also applies to hydraulic pumps and motors.

On modern hydraulic transmissions, shaft packing materials are of five general classifications: synthetic rubber, fluorinated compounds, silicones, fabric and rubber combinations, and leather. The hydraulic fluid to be sealed determines the type of packing material to be used. Packings for use in hydraulic systems containing petroleum-base fluid cannot be used in systems using phosphate ester fluids and vice versa. Water-glycol fire-resistant fluids and water-petroleum oil-emulsion fluids are generally compatible with any packings designed for petroleum oil.

The success or failure of any packing material depends upon more than compatibility of the fluid and the packing material. Other considerations are pressures, shock loads, clearances, surface finishes, temperatures, frequency and duration of work cycles. Packings should be installed in the sequence and direction given in applicable instruction manuals, or as the old ones are removed. Packing glands should only be tightened to the degree that leakage is kept to acceptable levels. Overtightening increases friction and shortens packing life.

There is less likelihood of *poor alignment between the driving and driven members* of a hydraulic transmission if the wedges, shims, jacking screws, or adjusting setscrews are properly set and secured when connected units are installed. However, because of a casualty, misalignment may cause severe stress and strain on the coupling and connected parts. Misalignment should be eliminated as soon as possible by replacing any defective parts and readjusting the installed aligning devices. If this is not done, pins, bushings, and bearings will have to be replaced frequently.

Since there is no end play to either the pump or motor shaft, flexible couplings are generally used in hydraulic transmissions. Such couplings permit satisfactory operation with a slight misalignment, without requiring frequent renewal of parts.

MAINTENANCE

Regular operation, proper lubrication, proper maintenance of all the units, and cleanliness of the fluid are principal requirements for keeping a hydraulic transmission in satisfactory operating condition. Regular operation of hydraulic equipment prevents corrosion, sludge accumulation, and freezing of adjacent parts. The need for proper lubrication and cleanliness cannot be too strongly emphasized.

Detailed instructions on the maintenance of a specific unit may be obtained from the PMS and the appropriate instruction book. However, the general information that follows will also be helpful.

In attempting to locate the source of any problem in an electrohydraulic system, remember that all problems will be in one of three categories—hydraulic, electric, or mechanical. Isolating a problem into one of these categories is one of the primary steps in locating the source of trouble.

Hydraulic Casualties

These casualties are generally the result of low oil levels, external or internal leakage, clogged lines or fittings, or improperly adjusted valves and other working parts. Do not disassemble a unit unless you are certain that the trouble exists within that unit. Unnecessary disassembly can lead to additional trouble, because of the dirt that may enter an open system.

Leaks are a frequent cause of trouble in hydraulic equipment. Leaks are generally caused by excessively worn parts, by abnormal and continuous vibration, by excessively high operating pressures, or by faulty or careless assembly. External leaks usually have little effect on the operation of equipment other than a steady draining of the oil supply. Still, even a small leak wastes oil, and the resulting unsightly appearance of a machine is indicative of poor maintenance.

External leaks may result from any of the following causes: improperly tightened threaded fittings; crossed threads in fittings; improperly fitted or damaged gaskets; distorted or scored sealing rings, oil seals, or packing rings; scored surfaces of working parts; improperly flared tube ends; or flanged joints not sealing squarely.

Internal leaks, however, generally result in unsatisfactory operation of the equipment. Large internal leaks are indicated by loss of pressure and failure of equipment. Large internal leaks can usually be located by installing a pressure gauge in various parts of the equipment. The location of small leaks generally requires disassembly and visual inspection of the parts. Internal leaks may result from worn or scored valves, pistons, valve plates, or bushings, or from improperly fitted or damaged gaskets.

The symptoms of trouble in a hydraulic system are frequently in the form of unusual noises. Some noises are characteristic of normal operation and can be disregarded, while others are evidence of serious trouble. Even though the exact sound indicating trouble can be learned only through practical experience, the following descriptive terms will give a general idea of the noises that are trouble warnings.

POPPING and SPUTTERING noises indicate that air is entering the pump intake line. Air entering the system at this point may be the result of too small an intake pipe, an air leak in the suction line, a low oil level in the supply tank, cold or heavy oil, or the use of improper oil.

If air becomes trapped in a hydraulic system, HAMMERING will occur in the equipment or in the transmission lines. If hammering occurs, check for improper venting. In some cases, a POUNDING or RATTLING noise occurs as a result of a partial vacuum produced in the active fluid during high-speed operation or when a heavy load is applied. This noise may be unavoidable under the conditions stated and can be overlooked if it stops when speed or load is reduced. If the noise continues at low speeds or light loads, the system should be vented of air. Air in a hydraulic system can also cause uneven motion of the hydraulic motor.

The cause of a GRINDING noise is most likely to be dry bearings, foreign matter in the oil, worn or scored parts, or overtightness of some adjustment.

HYDRAULIC CHATTER is a term sometimes used to identify noises caused by a vibrating spring-actuated valve, by long pipes improperly secured, by air in the lines, or by binding of some part of the equipment.

If the packing is too tight around some moving part, SQUEALS or SQUEAKS may occur. This type of noise might also indicate that a high-frequency vibration is occurring in a relief valve.

Electrical Casualties

Although the EM is responsible for checking electrical equipment troubles, you can help by making a few simple tests when electrical troubles occur. Such an oversight as not having a switch in the ON position may be the reason for equipment failing to operate. If the circuit is closed and the equipment still fails to operate, check for blown fuses and tripped circuit breakers. These troubles generally result from an overload on the equipment. If a circuit breaker continues to open, the problem may be damaged equipment, excessive binding in the electric motor, obstruction in the hydraulic transmission lines, or faulty operation of the circuit breaker. Another source of electrical problems may be in the circuit; check for open or shorted leads, faulty switches, and loose connections.

Mechanical Casualties

An electrohydraulically driven auxiliary may become inoperative because of a mechanical failure. If so, check for improper adjustment or misalignment of parts, shearing of pins or keys, or breakage of gearing, shafting, or linkage. Elimination of troubles resulting from any of these causes should be accomplished in accordance with the manufacturer's instructions for the specific equipment.

COMPRESSED AIR SYSTEMS

In working with any of the three types of compressed air systems (low-, medium-, and high-pressure), you probably found that the compressor caused most of the problems. The design and capacity of compressors vary, but the maintenance procedures are essentially the same. However, remember that the care and maintenance of high-pressure compressors requires additional safety precautions. Always follow the procedures recommended by the manufacturer.

While modern compressed air systems are rugged and dependable, they are not designed to withstand abusive treatment. Gasketed joints, pipe joints, and bolts will safely withstand the strain required for a tight connection when the specified torque is applied with the correct tool. The application of greater force usually results in breakage. If a joint or bolt cannot be tightened without using an oversized wrench or wrench handle extension, there is probably something wrong with the assembly.

CARE AND MAINTENANCE OF AIR COMPRESSORS

The overall goal in maintaining compressed air systems is to prevent a reduction in compressor capacity. You need to keep a ship's air compressor operating efficiently at all times and prevent as many troubles as possible. To do that, you must know how to care for air intakes and filters; how

to maintain and replace air valves; how to take care of air cylinders, pistons, and wrist pins; how to adjust bearings, couplings, and so forth; and how to maintain the lubrication, cooling, control, and air systems.

Air Intakes and Intake Filters

Satisfactory operation of any compressor requires a supply of clean, cool, dry air. To help keep the air supply clean, filters are fitted to compressor intakes. Unless these filters are inspected and cleaned regularly they will become clogged and cause a loss of capacity.

To clean filter elements, remove them from the intake and wash them with a jet of hot water or steam, or immerse them in a strong solution of washing soda. The filter body should be drained and replaced. Filter elements of the oil-wetted type should be dipped in clean oil after cleaning. Before replacing the element in the intake, let excess oil drain from it. The use of gasoline or kerosene is prohibited for cleaning air filters, because of explosive fumes that may collect in the compressor or air receiver.

Air Valves

The inlet and discharge valves of compressors require special attention. When valves leak, compressor capacity is reduced and pressure is affected. Deviation from normal intercooler pressure may indicate a leaking or broken valve, rise in pressure indicates a defective inlet valve, and a decrease in pressure indicates a defective discharge valve. Another sign of valve trouble is an unusually hot valve cover.

Dirt is generally the cause of leaking valves. When valves become dirty, the source of trouble can usually be traced to dirty intake air; use of an excessive amount, or of an improper grade, of cylinder oil; or excessively high air temperature, resulting from faulty cooling. Periodic inspection and cleaning of valves and valve passages minimizes the number of air valve troubles.

When air valves are removed for inspection, mark each valve to ensure that it will be replaced in the same opening from which it was removed. Inspect valves carefully and do not disassemble them for cleaning unless their condition necessitates such action. Dirt or carbon can usually be removed from valve parts without disassembling the valve. If it becomes necessary to disassemble the valve, note the arrangement of the various parts so that the proper relationship will be kept when the valve is reassembled. To remove carbon from valve parts, soak the individual part in a suitable solvent and then brush or scrape it lightly. After drying and reassembling the valve parts, test the operation of the valve to see if it opens and closes freely.

Before replacing air valves in a cylinder, inspect the gaskets. If other than copper, replace any gaskets that are damaged. Copper gaskets should always be replaced. Since it may be difficult to distinguish between suction and discharge valves, extreme care must be taken when the valves are being inserted in the cylinder. Make certain that suction valves open TOWARD and discharge valves AWAY FROM the center of the cylinder; otherwise, serious damage or loss of capacity will result. In most instances, special lock nuts are provided to seal against leakage at the threads of the valve setscrew.

Cylinders, Pistons, and Related Parts

You should be familiar with the procedures for cleaning cylinders, removing pistons, fitting new piston rings, replacing cylinders, checking piston end clearances, adjusting bearings, replacing wrist pins, packing stuffing boxes, and caring for couplings and V-belts. Follow the maintenance procedures recommended by the manufacturer and observe all safety precautions as you do the work.

Control Devices

Because of the great variety of controls regulating the unloading devices used with compressors, detailed instructions on their adjustment and maintenance must be obtained from manufacturers' instruction books.

If a control valve fails to operate properly, disassembly and a thorough cleaning will usually be necessary. Some control valves are fitted with filters filled with sponge or woolen yarn to prevent dust and grit from being carried into the valve chamber. These filters also remove the gummy deposit that comes from the oil used in the compressor cylinders. The filter element should be replaced with the specified material each time a valve is cleaned. Do not use cotton, because it will pack down and stop the air flow.

Since relief valves ensure safe operation of a compressed air system, they must be maintained in satisfactory operating conditions at all times. Relief valves should be set as specified by the manufacturer. They should be tested in accordance with the PMS.

AIR COMPRESSORS

The one nonreciprocating type of air compressor that is found aboard ship is referred to as a rotary compressor, a centrifugal compressor, or a "liquid piston" compressor. Actually, the unit is something of a mixture, operating partly on rotary principles and partly on centrifugal principles. It might be called a rotary-centrifugal compressor, and we will use that term here.

The rotary-centrifugal compressor is used to supply low-pressure compressed air. Because this compressor is capable of supply air that is completely free of oil, it is often used as the compressor for pneumatic control systems and for other applications where oil-free air is required.

The rotary-centrifugal compressor, shown in figure 9-1, consists of a round, multibladed rotor that revolves freely in an elliptical casing. The elliptical casing is partially filled with high-purity water. The curved rotor blades project radially from the hub. The blades, together with the side shrouds, form a series of pockets or buckets around the periphery. The rotor is keyed to the shaft of an electric motor. It revolves at a speed high enough to throw the liquid out from the center by centrifugal force. This results in a solid ring of liquid revolving in the casing at the same speed as the rotor but following the elliptical shape of the casing. This action alternately forces the liquid to enter and recede from the buckets in the rotor at high velocity.

To follow through a complete cycle of operation, let us start at point A. The chamber (1) is full of liquid. The liquid, because of centrifugal force, follows the casing, withdraws from the rotor, and pulls air in through the inlet port. At (2) the liquid has been thrown outward from the chamber in the rotor and has been replaced with atmospheric air. As the rotation continues, the converging wall (3) of the casing forces the liquid back into the rotor chamber, compressing the trapped air and forcing it out through the discharge port. The rotor chamber (4) is now full of liquid and ready to repeat the cycle, which takes place twice in each revolution.

A small amount of seal water must be constantly supplied to the compressor. This makes up for the water that is carried over with the compressed air and removed in a refrigeration-type dehydrator.

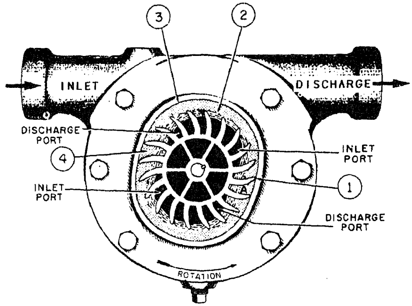

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Figure 9-1.—Rotary-centrifugal compressor.

CARE AND MAINTENANCE OF AIR SYSTEM EQUIPMENT

The care and maintenance of air system equipment includes inspections, cleaning, testing, and repairing. These activities should be done in accordance with the PMS.

Surface Inspections and Maintenance

The air flasks, high-pressure piping, and separators are inspected in accordance with the PMS. These inspections are made to determine if there is any external corrosion or damage to flasks or piping. Air flasks must be blown down weekly. Moisture separators installed downstream of the compressor must be blown down hourly during operation of the compressor. Filter elements must be changed in accordance with existing instructions.

The drainage of air system equipment must be sufficiently frequent to prevent excessive accumulations of moisture and oil. Such accumulations not only cause internal corrosion and fouling of moving parts, but also create a serious hazard in that excessive oil accumulation may cause an explosion.

Inspection, Cleaning, and Testing By Repair Activities

In addition to shipboard inspection and maintenance of high-pressure air flasks and separators, there must be inspections, cleaning, testing, and repainting performed at prescribed intervals by a repair activity.

INSPECTIONS AND MAINTENANCE

Minimum requirements for the performance of inspections and maintenance on high-pressure air plants are listed in the PMS.

It is the responsibility of the engineering officer to determine if the condition of the equipment, hours of service, or operating conditions necessitate more frequent inspections and tests. Details for outline tests and inspections may be obtained from the appropriate manufacturer's instruction book or from the *Naval Ships' Technical Manual.*

SAFETY PRECAUTIONS

There are many hazards associated with the process of air compression. Serious explosions have occurred in high-pressure air systems because of a diesel effect. Ignition temperatures may result from rapid pressurization of a low-pressure dead-end portion of the piping system, malfunctioning of compressor aftercoolers, leaky or dirty valves, and many other causes. Every precaution must be taken to have only clean, dry air at the compressor inlet.

Air compressor accidents have also been caused by improper maintenance procedures. Some examples are disconnecting parts while they are under pressure, replacing parts with units designed for lower pressures, and installing stop valves or check valves in improper locations. Improper operating procedures have also caused air compressor accidents with resulting serious injury to personnel and damage to equipment.

In order to minimize the hazards of compression and the use of compressed air, all safety precautions outlined in the manufacturers' technical manuals and in the *Naval Ships' Technical Manual* must be strictly observed.

CHAPTER 10

PROPULSION PLANT EFFICIENCY

The military value of a naval ship depends to a large extent on its cruising radius, which in turn depends upon the efficiency with which a propulsion plant is operated. Economical operation involves making fuel, lubricating oil, boiler feed water, potable water, and consumable supplies last as long as possible. A ship is not ready for wartime steaming unless the engineering department can and does operate reliably and efficiently. It is, therefore, important that engineering personnel maintain propulsion equipment in a reliable condition and that the equipment be operated at maximum efficiency.

The primary purpose of the peacetime Navy is to train and prepare personnel for wartime conditions. However, in peacetime, maximum economy must be practiced to keep operating and maintenance costs at a minimum.

The operation of an engineering plant cannot be considered reliable when machinery casualties occur frequently. Some of the more common causes of machinery casualties are

1. changing the setup of the plant at high speeds;
2. radical maneuvering of the ship;
3. inexperienced or improperly trained personnel;
4. inattentive watch standing;
5. poor supervision; and
6. inadequate repairs, maintenance, and preventive maintenance.

Accurate knowledge and continuous effort are required to keep propulsion plants operating reliably and efficiently. It is necessary for the personnel concerned to be familiar with the chapters of the *Naval Ships' Technical Manual* that deal with main propulsion plants and associated auxiliary equipment. It is also necessary for personnel to have an accurate knowledge of the appropriate manufacturer's technical manuals, official publications, and directives on operational procedures and material upkeep.

When a ship is underway, the MMC or MM1 will normally stand watch as the engineering officer of the watch (EOOW). The engine-room supervisor must be capable of supervising all the operations of the propulsion and auxiliary machinery and of preparing systems applicable to the engine room assigned. The EOOW must be capable of supervising the entire propulsion plant, which includes the other engine room(s) and the firerooms.

On ships having more than one main propulsion plant, the associated engine room and fireroom are usually operated together as one unit. On some auxiliary ships this one unit constitutes the entire propulsion plant; on combatant ships, this unit may be one of two or four separate propulsion plants. The physical characteristics of compartments and bulkheads, or the location and arrangement of machinery and equipment, do not change the operating principles of a main propulsion plant. On older ships, it was necessary to operate two separate spaces as one basic unit; however, on most new large combatant ships, NAVSEA has changed this arrangement. The present machinery arrangement has the basic propulsion plant, consisting of boilers, main engines, turbogenerators, and auxiliary machinery of the associated engine room and fireroom, in one compartment. This compartment is called a main machinery room.

In operating the associated engine room and fireroom as one complete propulsion plant, maximum reliability and efficiency cannot be obtained unless there is cooperation, understanding, and teamwork between engine-room and fireroom personnel. A great deal depends upon the knowledge and supervisory ability of the senior watch stander in each main machinery space. The MM in charge of the engine room should have a practical knowledge of fireroom operation, of safety precautions, and of the casualties that may occur during operation of the engineering plant.

The EOOW must see that the officer of the deck (OOD) and the engineer officer are immediately informed of all important facts concerning the operation of the main engines. The EOOW is responsible for reporting to the engineer officer and the OOD such items as casualties to machinery, boilers available, generators available, and maximum speed at which the ship is capable. The EOOW must also report such operations as placing a major unit of machinery in or out of commission and starting or securing a piece of machinery. He/she must be capable of carrying out appropriate engineering casualty control procedures for the overall operation of the propulsion plant in order to minimize the effect of the casualty on the the overall operation of the plant.

ENGINEERING PERFORMANCE

During peacetime, the objective of engineering department training in the fleet is to create and maintain readiness to deliver the designed performance of the engineering plant at all times. Such readiness includes the ability to operate free of breakdowns, to control engineering damage, to make prompt and effective emergency repairs, and to operate the engineering plant safely and economically. Administrative instructions are provided each ship for the purpose of furnishing a general and uniform guide by which type commanders or their subordinates may estimate or evaluate the engineering performance and readiness of the ships assigned to their command.

ENGINEERING RELIABILITY

A ship must be capable of performing any duty for which it was designed. A ship is considered reliable when it meets all scheduled operations and is in a position to accept unscheduled tasks. In order to do this, the ship's machinery must be kept in good condition so that the various units will operate as designed. Some of the steps to promote reliability are as follows:

1. A good preventive maintenance program must be carried out at all times. This involves regular tests, inspections, and repairs.
2. Machinery and piping systems must be operated in accordance with good engineering practices. Operating instructions and safety precautions should be posted for each unit of machinery.
3. Supervisory personnel must have a thorough knowledge of the ship's machinery and piping systems. Information on construction, operation, maintenance, and repair of machinery can be obtained from the manufacturer's technical manuals and blueprints.
4. A good engineering department administrative organization will ensure proper assignment of duties and responsibilities and proper training and supervision of personnel. The MMC and MM1 will have administrative and supervisory duties. As a supervisor, the MMC or MM1 must see that all pertinent instructions and procedures are carried out in regard to the proper operation, maintenance, and repair of machinery.
5. Personnel must be thoroughly trained. This can best be accomplished by a combination of methods. An effective method of training is to have the students learn by doing; a good example of this is watch standing. Another method of training is carrying out regularly scheduled and well-planned instruction periods. These instruction periods are not limited to classroom instruction—they may be conducted by holding engineering casualty control drills while underway.

The Personnel Qualification Standards provide the minimum requirements necessary to qualify on a watch station.

ENGINEERING PLANT ECONOMY

In order to obtain economy, the engineering plant, while meeting prescribed requirements, must be operated so as to use a minimum amount of fuel. THE FUEL PERFORMANCE RATIOS ARE GOOD OVERALL INDICATIONS OF THE CONDITION OF THE ENGINEERING PLANT AND THE EFFICIENCY OF THE OPERATING PERSONNEL. The fuel performance ratio is the ratio of the amount of fuel oil used to the amount of fuel oil allowed for a certain speed or steaming condition. The fuel performance ratio is a general indication of the ship's readiness to operate economically and within established standards. In determining the economy of a ship's engineering plant, the same consideration is given to the amount of water used on board ship. Water consumption is computed in (1) gallons of makeup feed per engine mile, (2) gallons of makeup feed per hour at anchor, and (3) gallons of potable water per person per day.

The increase or decrease in a ship's fuel economy depends largely on the operation of each unit of machinery; economical operation further depends on personnel understanding the function of each unit and knowing how units are used in combination with other units and with the plant as a whole.

Good engineering practices and safe operation of the plant should never be violated in the interest of economy—furthermore, factors affecting the health and comfort of the crew should meet the standards set by the Navy.

Indoctrination of the ship's crew in methods of conserving water is of the utmost importance, and it should be given constant consideration.

Economy Versus Safety

Aboard naval ships, economy measures cannot be carried to extremes because there are several safety factors that must be considered. Unless proper safety precautions are taken, reliability may be sacrificed; and in the operation of naval ships, reliability is one of the more important factors. In operating an engineering plant as economically as possible, safety factors and good engineering practice must not be overlooked.

Notes on Efficient Operation

There are several factors that, if given proper consideration, will promote efficient and economical operation of the engineering plant. Some of these factors are (1) maintaining the designed steam pressure, (2) proper acceleration of the main engines, (3) maintaining designed condenser vacuum, (4) guarding against excessive recirculation of condensate, (5) maintenance of proper insulation and lagging, (6) keeping the consumption of feed water and potable water within reasonable limits, (7) conserving electrical power, (8) using the correct number of boilers for best efficiency at the required load levels, and (9) maintaining minimum excess combustion air to the boilers.

MAINTAINING A CONSTANT STEAM PRESSURE is important to the overall efficiency of the engineering plant. Wide or frequent fluctuations in the steam pressure or degree of superheat above or below that for which the machinery is designed will result in a considerable loss of economy. Excessively high temperatures will result in severe damage to superheaters, piping, and machinery.

PROPER ACCELERATION AND DECELERATION OF THE MAIN ENGINES is an important factor in the economical operation of the engineering plant. A fast acceleration will not only interfere with the safe operation of the boilers but will also result in a large waste of fuel oil. The Machinist's Mate in charge of an engine-room watch, or standing throttle watch, can contribute a great deal to the economical and safe operation of the boilers.

A HIGH CONDENSER VACUUM can be obtained only by the proper operation and proper maintenance of the condenser. A low exhaust pressure (high vacuum) is an important factor in obtaining maximum engineering efficiency. Steam exhausting into a low-pressure area has a greater range of expansion and therefore is capable of accomplishing more useful work. The total available energy in the steam is much higher per pound of pressure difference in the lower range of pressures than in the upper range. This is the most important reason why the condenser vacuum should be maintained as high as possible.

EXCESSIVE RECIRCULATION OF CONDENSATE should be avoided as it cools the condensate, which then has to be reheated as it enters the deaerating feed tank. This reheating process causes an excessive amount of steam to be used to maintain the proper temperature in the deaerating feed tank.

MAINTENANCE OF PROPER INSULATION AND LAGGING not only increases the overall economy of the engineering plant but also is a safety measure and increases the comfort of personnel. In every power plant there is a heat loss as heat flows from heated surfaces, such as piping and machinery, to the surrounding air and cooler objects. This heat loss can be kept to a minimum by proper insulation.

While increasing the economy of the plant, insulation also reduces the quantity of air necessary for ventilating and cooling the space. Proper insulation also reduces the danger of personnel receiving burns from contact with the hot parts of the piping, valves, and machinery. Good insulation, elimination of steam leaks, and a clean ventilation system contribute to good economy and to the comfort and safety of personnel.

CONSERVATION OF FEED WATER AND POTABLE WATER has a direct bearing on the overall efficiency and economy of the ship. Feed water and potable water consumption rates are entered on the fuel and water report. Type

commanders use these consumption rates as a factor for judging the efficiency of ships operating under their command. Ships having excessive feed water consumption rates should take immediate steps to eliminate all steam and water leaks, which contribute to the uneconomical operation of the plant. Improving feed water consumption rates will also improve the fuel oil performance ratio.

The consumption of potable water by the ship's crew bears a direct relationship to the efficient operation of the engineering plant; the greater the amount of fresh water distilled, the greater the amount of steam used. Conservation of fresh water requires the close cooperation of all personnel aboard ship, since large amounts may be wasted by improper use of the laundry, scullery, galley, and showers.

FAILURE TO CONSERVE ELECTRICAL POWER is a very common source of waste aboard ship. Lights are frequently left on when not needed, and bulbs of greater wattage than required are often used.

If the ship's ventilation system is improperly operated or improperly maintained, the result is a waste of electrical power. Vent sets are often operated on high speed when low-speed operation would provide adequate ventilation and cooling. Dirty and partially clogged ventilation screens, heaters, cooling units, and ducts will result in inefficient operation and power loss.

In checking the operation of the engineering plant for efficiency, consider the proper operation and maintenance of all units of auxiliary machinery. Economical operation of the distilling plants and of the air compressors will contribute a great deal to the overall efficiency of the plant. Because of the large number and various types of pumps aboard ship, their operation and maintenance are important factors. Units of machinery that operate continuously (or most of the time) must be given careful attention with respect to efficient operation and maintenance.

The following are specific recommendations for the efficient operation of engineering plants:

- Maintain superheated steam temperature as close to the designed temperature as operating conditions permit.

- Boiler casings should always be tight. Leaky casings result in excessive fuel consumption because additional steam is required to increase blower capacity and heat is conducted away from the boiler by leaking air.

- High feed water consumption indicates an uneconomical plant. No feed water leak is too small to be neglected.

- Keep the steam pressure temperature as steady as is feasible at all times.

- Throttlemen must carefully follow the acceleration and deceleration table posted on the throttle board.

- Check the condensing system frequently for proper operation and tightness.

- Check the operation of the deaerating feed tank frequently.

- Keep all drain valves, drain lines, and steam traps in good working condition.

- Check all orifice plates in piping systems for good material condition, proper size, and proper operation.

- Keep the steam pressure to the air ejectors steady and at the designed pressure.

- Keep the auxiliary exhaust pressure at the designated value by maintaining the automatic dumping valves in good working condition.

- Maintain all insulation and lagging in good condition.

- Keep the bilges dry. Water in the bilges will add to the humidity of the air, necessitating more ventilation and causing bilge piping to corrode.

- Keep ventilation systems clean at all times.

- Run ventilation motors on low speed unless high speeds are necessary.

- Whenever the ship's electrical load will permit, operate one generator, rather than two. It is more economical to operate one generator at nearly full load than to operate two generators at light loads.

- Maintain proper lubricating oil temperatures. Cold lube oil can be an indirect cause of excess fuel oil consumption and improper bearing lubrication.

- Use the proper number of boilers for best efficiency at the required load condition.

- Use the proper setup of pumps and other auxiliaries at all times.

- Keep heat exchangers, such as lube oil coolers, operating efficiently.

- Keep the condensate depression between 0°F and 2°F.

- Never sacrifice safety for economy. Personnel may be injured and machinery may be damaged.

Trial Performances

Trial performances, such as full power and economy trials, are conducted to furnish evidence of the ship's engineering plant readiness for peacetime or wartime steaming conditions. By studying the trial performance reports, the type commander and NAVSEA can evaluate the ship's readiness to make required speeds and economy of operation. Information on conducting trial performances will be given in a later chapter of this training manual.

CONTROL OF ENGINEERING CASUALTIES

The ability of engineering department personnel to control engineering damage and make emergency repairs is measured by PERFORMANCE OBSERVED during training exercises and actual emergencies. The first consideration in judging the effectiveness of engineering casualty control lies in evaluating the ability of the ship's force to maintain and repair the ship's machinery and equipment. For complete evaluation, allowances must be made for the age, service, and character of the installed machinery, for time and facilities allotted for maintenance and repair, and for experience and training of engineering personnel.

Another means of judging the readiness and ability of a ship and the ship's crew to perform the operations that might be required of them in time of war is by conducting an OPERATIONAL READINESS INSPECTION (ORI). The ORI consists of conducting battle problems and other operational exercises that involve all divisions aboard ship. The results of the engineering casualty control exercises greatly reflect the condition of the machinery and the effectiveness of the personnel. During such an exercise, too much dependence should not be placed on a few key personnel. All personnel should be trained so that smooth teamwork and reliable performance may be obtained.

Careful and continuous efforts by the MM1 and MMC must be carried out to train personnel on steaming watch. In peacetime, almost all of the engineering casualties occur during a steaming watch, at which time the key personnel may not be present. These casualties must be handled by the personnel on watch at the time when they occur. The senior watch standers should check the training of their watch standers and have a thorough knowledge of both their ability to stand watch and to handle casualties. The senior watch standers should take all practical steps to instruct and train personnel on watch.

GETTING READY TO GET UNDERWAY

Getting a ship underway, especially a large ship, in a smooth and efficient manner depends to a great extent upon the administrative procedures and organization of the engineering department. Posting the steaming watch, providing advanced information to supervisory personnel, disseminating instructions to watch standers, mustering and checking watch standers on stations, and warming up the main plant and standing by to get underway, require certain procedures, coordination, and instructions by supervisory personnel.

To prevent misunderstanding and confusion, forms and check-off lists are used in getting the engineering plant ready to get underway. The purpose of check-off sheets for warming up or securing a main plant is to provide a convenient and simple procedure for checking the required steps in proper sequence. Check-off sheets will ensure that no important step is overlooked or forgotten.

STEAMING ORDERS

Steaming orders are usually written by the engineer officer or the main propulsion assistant. Steaming orders are necessary, especially on large ships, to supply advance information to supervisory personnel and to enable administrative personnel to make necessary preparations.

Steaming orders list the various units of machinery and the readiness requirements of the engineering department. This form usually includes the major machinery to be used, the

lighting-off times, the cutting in of boilers, spinning of main engines, the times of warming up and putting ship's service generators on the line, standard speed, the name of the engineer officer of the watch, the name of the leading petty officer of the watch, and any additional information that the engineer officer thinks necessary. The steaming orders are generally written the night before the ship is to get underway and left in a convenient location, such as the log room or central control, for the duty officers and duty petty officers to sign. When a petty officer signs the steaming orders, it means that he/she has read and understood the orders and therefore is fully responsible for carrying out any and all applicable orders. The early posting of such orders is essential in getting a large propulsion plant underway with a minimum of confusion.

On smaller ships, such as destroyers, steaming orders are usually brief and simplified. The first part of the engine-room lighting-off sheet is generally used as the steaming orders. Key personnel, such as the MMC, BTC, and EMC, are notified by the engineer officer or by the assistant engineer officer as to the time the ship will get underway. The duty MMC, who has received all the necessary information and instructions, is responsible for making preparations for getting underway.

WARMING UP THE PROPULSION PLANT

When all watch standers have been mustered in the engine room or machinery room, the petty officer in charge of the watch should inform main engine control that his/her space is manned and ready to light off. The officer of the watch or the senior petty officer in main engine control must check to see that all spaces are manned and ready to warm up the main propulsion plant. The officer of the watch or the petty officer who is assuming the duties of the officer of the watch must also see that all other required reports are made to main engine control.

At the time specified by the steaming orders, the senior watch stander will direct the spaces to start warming up the plant in accordance with the engineering operational sequencing system (EOSS).

Many casualties that have occurred during warming up the plant can be traced directly to lack of cooperation between engine-room and fireroom personnel, misunderstanding of orders, lack of coordination by the senior watch stander, starting or securing machinery without orders, and opening or closing valves without orders to do so.

It is very important to hold the boiler load to a minimum until the main feed pump can be warmed up and is ready to feed the boiler. On ships using an emergency feed pump for feeding the in-port boiler, it is very important to warm up the main feed pump as soon as possible. As additional machinery is started, the load on the emergency feed pump increases. Emergency feed pumps are designed to feed a boiler at low loads only; a main feed pump should take the load as soon as one is warmed up and ready to be put on the line.

When an additional boiler is ready to be brought on line, the officer of the watch must carefully coordinate the efforts of the engine-room and fireroom watch standers to prevent casualties. Putting another boiler into service involves starting additional feed booster pumps, main feed pumps, another deaerating feed tank, and splitting the plant. At this point in the warming up process, a lack of cooperation or a misunderstood order can cause several different kinds of casualties; an empty deaerating feed tank, loss of main feed pressure, or loss of electrical power are but a few of the casualties that have occurred. Split-plant valves should never be opened or closed without orders from the officer of the watch in main engine control, and when such orders are received the valves should be opened (or closed) as soon as possible.

REPORTING READY TO ANSWER BELLS

During the last few minutes before the ship is scheduled to get underway, the officer of the watch has many duties and responsibilities to carry out. The officer of the watch must

1. be certain that the items listed on the steaming orders are carried out or will be carried out according to the engineer officer's orders;
2. know that all required machinery has been warmed up properly, put on the line, and is running normally;
3. be sure that the required boilers are on the line, that all main steam lines have been properly drained and lined up as specified by the lighting-off sheets;
4. ensure that the required number of ship's service generators are on the line, and that the electrical load is split;

5. be sure that the Electrician's Mates and IC Electricians have tested the engine order telegraph, the shaft revolution indicator, the steering engines, and the anchor windlass; and

6. know that the plant is split and that all standby machinery has been tested and is ready for use, if needed.

The main engines must be tested before the engineering plant is ready to get underway. On a small ship, such as a destroyer, the EOOW will request permission from the OOD to test main engines, usually about 15 minutes before the ship is scheduled to get underway. On a large ship, such as a CVA, this request may be made 1 hour or more before the scheduled departure time.

When the OOD is certain that the area around the screws is clear of boats, lines, or other objects that may foul the screws, he/she will grant permission to test the main engines. When this permission has been granted, the EOOW must notify all engineering spaces. When all main engines have been tested satisfactorily, the EOOW will report to the OOD that the engineering department is ready to get underway.

After the main engines have been tested, and while you are waiting to answer bells, the main engines must be turned by steam. The engines are spun, astern and then ahead, to prevent putting way on the ship. Spinning the engines not only heats the casings but also prevents the rotors from bowing. The interval of time between testing main engines and getting underway may be prolonged by weather, traffic, casualties, or other conditions; during this time the main engines must be turned by steam at least once every 3 to 5 minutes. However, if the getting underway time is unduly delayed, the commanding officer may grant permission to engage and start turning gear to keep the engines turning.

FIREROOM OPERATIONS

In order for an MMC or MM1 to carry out his/her duties properly, he/she must possess some knowledge of basic fireroom procedures. This is especially true of those installations where an MMC is in charge of the control engine room while underway. The efficient and safe operation of the engineering plant depends to a large degree on close cooperation between the engine-room and fireroom personnel. This close cooperation will, in turn, depend on the MM's knowledge of the fireroom and the BT's knowledge of the engine room. By the time personnel in either space have become first class or chief petty officers, they should have a good knowledge of the entire engineering plant. This does not mean that they should be able to switch watch standing jobs, but they should have a good understanding of what is occurring on the other side of the bulkhead or, in some ships, on the other side of the space.

Close cooperation of personnel in both spaces is always important, and is especially important when warming up or securing the plant because this is the time when many casualties occur. As additional machinery is started in the fireroom, the engine room should be notified. In many instances, the fireroom should be notified as machinery is started or secured in the engine room. NEVER take for granted that personnel in other spaces know which machinery is in operation.

Most ships have single-furnace boilers; however, some of the older ships such as BB's have double-furnace boilers. The present discussion is limited to pointing out certain operational differences between double-furnace (controlled superheat) and single-furnace (non-controlled superheat) boilers, since these are currently the two most commonly used types.

The double-furnace boiler with controlled superheat is installed on many combatant ships built up to the end of World War II. The operating pressure of this type of boiler is approximately 615 psig with a maximum superheater outlet temperature of 850°F. The superheaters of these boilers cannot be fired safely unless there is a safe minimum flow of steam passing through the superheaters.

On large combatant ships, there is usually sufficient steam flow (even when steaming for auxiliary purposes) to maintain fires under the superheater side. However, in most installations, it is usually necessary to be underway and making about 12 knots before the fires can be lighted under the superheater side of the boiler. When the superheater is operating and the steam flow drops below a safe minimum, the superheater fires must be secured immediately.

From the standpoint of maintenance and repairs to the steam piping, turbine casings, and superheater handhole plates, it is not feasible to put superheaters into operation until it is expected that the ship's speed will be more than 10 knots for a considerable period of time. Furthermore, continually lighting off and securing the superheater fires will cause extensive steam leaks throughout the system subjected to fast changing temperature conditions. These steam leaks will

waste more fuel than could be saved by a few minutes of superheat operation.

The single-furnace boiler without controlled superheat creates a different type of problem. After the boiler is on the line and furnishing steam, there will be sufficient flow because all steam passes through the superheater. When this type of boiler is lighted off or secured, there is no normal flow of steam through the superheater and some means of flow must be established. This means that before a boiler is cut in and after it is removed from the line cooling steam must pass through the superheater.

The following brief discussion on the construction and operation of the single-furnace boiler with uncontrolled superheat will help you understand the need for protection steam during lighting-off and securing operations.

The superheater is installed within the banks of the generating tubes and receives heat from the same fire as the generating tubes. In operation, the steam is generated; but before any of it is used, it is routed through the superheater.

The steam used for auxiliary purposes must be desuperheated by passing it through a desuperheater that is submerged below the water level in the steam drum or water drum. When the boiler is steaming for auxiliary or underway purposes, there is a constant flow of steam through the superheater, sufficient to cool the superheater tubes. During the time when the boiler is lighted off, before the stops are opened—and also when the boiler is secured, after the stops are closed—there is no normal flow through the superheater. During this time there is heat in the furnace and the superheater tubes are subjected to this heat. If there is no steam flow through the superheater tubes during this period, the superheater will become overheated and damaged. This problem is overcome by piping steam from the auxiliary steam line (150-psi line), through the superheater tubes, and into the auxiliary exhaust line.

When the boiler pressure exceeds the 150 psi of the auxiliary steam line, steam flow must be provided through the superheater by the use of high-pressure drains, auxiliary machinery, and throttling the steam in the auxiliary exhaust line. The amount of oil fired in the boilers during light-off should be very carefully controlled to prevent overheating superheater tubes.

It is sometimes necessary to light off and put additional boilers on the line when a ship is underway. With noncontrol superheat boilers, the steps are much the same as for putting the first boiler or boilers on the line. With superheat control boilers, additional precautions must be taken.

When the steam lines are carrying superheated steam, it would be dangerous to admit saturated steam to the lines. It is not usually possible to establish enough steam flow to light off the superheaters of the incoming boilers, until the boilers are on the line. It is permissible to bring in the incoming boilers without their superheaters in operation, if the superheater outlet temperature of the steam boilers is lowered to 600°F. Lowering of the superheat temperature on the steaming boilers should be started in time so that the cutting-in temperature can be reached before the incoming boilers are up to operating pressure. <u>Except in an emergency, the temperature of the superheaters should NOT be lowered or raised at a faster rate than 50°F every 5 minutes.</u>

If the ship is operating at a speed that requires maximum or nearly maximum superheat temperature and the saturated side is being fired at maximum or near maximum, the officer of the watch must know and inform the bridge that the speed of the ship will have to be reduced in order to cut in additional boilers.

OPERATING THE PLANT UNDERWAY

After the ship is clear of the harbor, the commanding officer will order the special sea detail secured. With the ship underway, a considerable amount of attention must be given to the plant. Some of the important factors to be considered are pointed out in the following paragraphs.

OPERATING INSTRUCTIONS

In order to be a good operator, the MM must become acquainted with all standing orders and operating instructions for the ship. These are made up for each ship and show the various plant arrangements (split plant, cross-connected steaming, cruising arrangement, etc.) for the different speeds. Each watch stander must read and understand the steaming orders and any additional orders issued by the engineering officer.

MAIN CONDENSER VACUUM

Maintaining a designed vacuum in the main condenser makes available more useful work from

each pound of steam. This increases the maximum speed of the ship. The vacuum for which the turbine was designed must be maintained. Watch standers must give careful attention to detect and prevent air leaks into the main condensing system. In order to maintain a designed vacuum, the following precautions must be taken:

1. Keep gland packing in good condition.
2. Maintain gland seal steam at the required pressure (usually 1/2 to 2 psig).
3. Eliminate all air leaks into the condensing system.
4. Maintain adequate water in the reserve feed tank which is in use for makeup feed.
5. Ensure that throttles not in use do not leak. Any leakage of steam past a closed throttle will tend to raise the temperature and pressure within turbines not in use.

If the condenser vacuum is not as high as it should be in relation to the condenser load and the cooling water overboard temperature, some part of the condensing system is not functioning properly. The operator should check for malfunctioning of a condensate pump or air ejectors, and for an air leak in some part of the system under vacuum.

ACCELERATION AND DECELERATION CHART

Acceleration and deceleration charts are posted at each main engine throttle board. These charts give the exact amount of time that the throttleman should use in changing speed. When a speed change is ordered, the throttleman can instantly tell, by checking the chart, the minutes and seconds necessary to accelerate or decelerate to the new speed. Main engine control has tachometers indicating the rpm of each shaft. By checking these tachometers, the throttleman can coordinate the rpm of the shafts. If one throttleman accelerates or decelerates too fast or too slowly, it can be detected and corrected by the officer of the watch.

Improper acceleration or deceleration wastes fuel oil and, in general, promotes uneconomical operation of the main plant. Each throttleman should make a revolution-pressure table, which gives the approximate pressure required in the first stage of the high-pressure turbine to develop a certain rpm. By using this table and the acceleration and deceleration chart, the throttleman can not only promote efficient operation of the plant but also make his/her watch standing much easier. There must always be a complete understanding between the engine room and the bridge as to how many rpm are to be maintained for one-third, two-thirds, standard, and full speed. The throttleman should never relieve the watch without knowing the rpm for these speeds.

PREPARING TO ENTER PORT

While the ship is still out in the open sea, main engine control should request permission to pump bilges. The EOOW must keep in mind the guidelines set forth in the Environmental Protection Manual, OPNAVINST 6240.3, which governs the discharge of oily waste overboard. Both soil and waste drains of the CHT systems must be shifted from overboard into the holding tanks.

Permission to blow tubes on all steaming boilers must be requested from the officer of the deck and carried out accordingly. When the bilges have been pumped and tubes blown on all steaming boilers, a report must be made to the bridge.

On ships with controllable superheat boilers, it is necessary to lower the temperature of the superheated steam before entering port. Lowering the temperature and securing the superheaters require close cooperation between the bridge, the engine room, and the fireroom. The fireroom must receive word in sufficient time so that the burnerman can lower the superheat temperature at the proper rate. (Remember, superheat should NOT be raised or lowered at a rate greater than 50°F every 5 minutes.)

SECURING THE MAIN PLANT

After main engine control has been notified of the time the ship is expected to enter port, advance preparations can be made for entering port, securing the main plant, and setting the auxiliary watch. Personnel must be informed and given specific instructions. On most ships, especially on small ships, the MMC in charge of the watch will supervise the preparations for entering port and the operations that take place. The MMC and MM1 will also be concerned with the administrative procedures involved in bringing a ship into port, securing the main engines, and setting the auxiliary watch.

AUXILIARY MACHINERY

On installations where the turbogenerators exhaust to either the auxiliary or main condensers, the follwing procedure should be used:

1. Put the required auxiliary condensers in operation, and start the required number of ship's service turbogenerators. After sea detail is set, ensure that all turbogenerators are exhausting into their respective auxiliary condensers.
2. Warm up all auxiliary machinery that is to be used in anchoring or mooring the ship.
3. Shift the low-pressure drains to the auxiliary condenser. It is usually not good practice to shift the auxiliary exhaust to the auxiliary condenser until the main plant is at least partially secured. In most installations, the auxiliary exhaust will overload the auxiliary condenser, cause a loss of vacuum, and probably result in loss of one or more ship's service turbogenerators. The auxiliary exhaust should be dumped to the main condensers until the auxiliary condenser is safe from overheating.

SETTING THE AUXILIARY WATCH

Each ship or class of ships will have its own detailed forms for securing procedures. A procedure used for destroyers is described in *Machinist's Mate 3 & 2,* NAVEDTRA 10524-D.

The officer of the watch must coordinate the securing operations. Although securing sheets are provided for each space, the petty officer in charge of the space must secure in accordance with the orders of the officer of the watch. No split-plant valves should be opened or closed without specific orders from the officer of the watch. No machinery, especially ship's service turbogenerators, should be started or stopped without orders from the officer of the watch. No watch stander should take for granted that he/she knows what is going on in another space. Usually, only the officer of the watch knows what is going on in all spaces.

When the auxiliary watch is set, the officer of the watch or the MMC in charge of the watch will make a final inspection before reporting to the OOD. The officer of the watch must know the status of all machinery. He/she must be able to report to the engineering officer and the OOD that the auxiliary watch is set, which boiler(s) and ship's service generator(s) are in use; and the time of securing boilers, generators, and engines. The officer of the watch should also inform the OOD that the turning gears are engaged and turning, and approximately when they will be secured. The OOD enters this information in the deck log.

The officer of the watch or MMC in charge of the watch must also know what units of machinery, if any, will require repairs, the extent of the repairs, approximately how long the unit(s) will be out of commission, and the length of time that would be required to get the ship underway. All persons concerned, from the personnel actually doing the work to the commanding officer of the ship should know this information. The commanding officer must know at all times how long it will take to get the ship underway and the maximum speed of which the ship is capable. Transmittal of this information starts with the senior petty officer in each space and goes through the chain of command to the commanding officer.

SUMMARY

This chapter has covered the general operation of the engineering plant. Major areas of discussion were efficient operation of the plant; engineering casualty control; and lighting off, operating, and securing the plant. Proper operation and maintenance of the engineering plant cannot be overemphasized. Unless the engineering plant is kept in top operating condition by a well-trained crew, the ship may not be able to respond adequately to operational requirements.

CHAPTER 11

ENGINEERING ADMINISTRATION

The higher you go in the Navy, the more responsibility you will have for administration, supervision, and training. This chapter deals briefly with some of your administrative and supervisory responsibilities and then addresses certain aspects of your responsibility for training others.

Although it is possible to consider administration, supervision, and training as three separate areas of responsibility, during normal day-to-day operations the three cannot be totally separated. Much of your work requires you to administer, supervise, and train all at the same time.

These administrative, supervisory, and training tasks have a direct relationship to any assigned job. Materials, repair parts and tools must be available when they are needed; jobs must be scheduled with regard to the urgency of the work; records must be kept and reports must be submitted; and personnel must be in a continuous state of training so that they can assume increasingly important duties and responsibilities. The only way to keep things turning smoothly is to take your administrative, supervisory, and training responsibilities seriously.

ADMINISTRATION AND SUPERVISION

As a Machinist's Mate, you will have administrative and supervisory responsibilities in connection with engine-room operations, maintenance, and repair.

The engineering department administrative organization is set up to provide a means for the proper assignment of duties and for the proper supervision of personnel. However, no organization can run itself. Personnel—including you—are needed to see that all pertinent instructions are carried out; that all machinery, equipment, and piping systems are operated in accordance with good engineering practice; that operating instructions and safety precautions are posted by machinery and obeyed by all engine-room personnel; that all watch standers are properly supervised; that records and reports are filled in correctly and submitted as required; and that the entire engineering plant is operated with maximum reliability, efficiency, and safety.

Experience will soon teach you that administration and supervision are very closely related. Your administrative and supervisory roles require that you be a leader, possess common sense, and earn the respect of others. Many decisions are difficult to make. To be an effective decision maker, you must assemble pertinent facts, policies, and procedures; develop a course of action and evaluate possible alternatives; select the best course of action; and initiate the required action. When necessary, consult your superior prior to taking action. Every supervisor must face problems squarely and make timely and sound decisions. The supervisor who dodges responsibilities will soon find control of subordinates slipping away, discipline deteriorating, dissatisfaction with his/her supervision increasing, and effectiveness of the organization suffering.

If, as a supervisor, you establish and maintain a spirit of cooperation within your division and in the everyday dealings with other divisions and shops, you will find your job is much easier. Ship's readiness is the common purpose of the maintenance organization, and all ratings should share a common interest in achieving that purpose. A willingness by each individual to submerge personal interest in favor of getting the job done is a necessary prerequisite to cooperation. If your requests as a supervisor are reasonable, made well in advance (when possible), are understood, and provide all necessary information, they will generally induce cooperative action. If cooperation is lacking, check the facts to find out why. If subordinates are at fault, you can tell them directly and in a firm manner, taking into consideration the basic principles of good leadership.

Supervisory duties involve planning, direction, and control. Careful planning is an essential ingredient to effective supervision and minimizes other types of supervisory efforts when carefully executed. Time and effort invested in the process of careful planning are rarely wasted. Careful planning can result in job simplification and increased efficiency.

The effective supervisor initiates the planning process by identifying each specific job to be done by his/her personnel. With a routine clearly established, you will have time to devote to the exceptions that may arise. You will know the capacities, interests, weaknesses, and potentials of your personnel. Knowing each person's level of technical skill, motivation, ambitions, and personality characteristics will enable you to (1) assign the right person to the right job, (2) identify the training needed by each person to do a better job, and (3) establish the standard which each person can be expected to meet.

Once action has been initiated, the supervisor provides direction. This function of supervision is like that of a foreman. You must see that work is started and must know what is going on at all times. This does not mean, however, that you must always be physically present while the job is being done. You should train your subordinates to assume responsibility for the job in your absence so that no one is indispensable, including yourself. You should, however, be available when your personnel are working, and they should know how to contact you. You should always be present when your personnel are assigned new tasks, when they have trouble getting a job done, or when other circumstances dictate the necessity for your presence. You must be careful not to oversupervise. Doing so might destroy the initiative of your workers and subordinate supervisors. You should receive suggestions and reactions from your subordinates and act as necessary on them, giving credit when and where it is due. Recognition for each person as an individual is required.

To be a successful supervisor, you must be able to control jobs. Control of a job means checking to see that the job is done as planned—a comparing of performance with plans. For most jobs, your subordinates should not deviate from your job plan. However, you should be flexible enough to allow changes if part of your job plan was faulty or if a truly better way of doing the job is suggested.

You will be challenged to allocate sufficient time for planning, direction, and control. But be assured, a spirit of firmness, fairness, cooperation, decisiveness, harmony, and mutual respect while seeing that the job is done will rarely go unrewarded.

COMMUNICATIONS

The area of communications related to administration and supervision is singled out here because of its importance. Almost without exception, problem areas regardless of their nature can be attributed to the lack of proper communications. People like to be kept informed about all the things that affect them. Keeping them informed will improve their morale and generally make them more responsive to the needs of the command. You can improve morale by keeping your personnel as well informed as possible concerning need-to-know and nice-to-know information that could affect them, as long as it is not classified.

Communications is a two-way process. You must be able to convey your ideas, orders, and so forth, and pass on information, either orally or in writing, so that it will be clearly understood. You must also be willing to listen to and try to understand the ideas of others. Subjectivity (that is, looking at things only from a personal viewpoint, because of your position, rating, pay grade, or any other reason) will hinder communications. Bias and limited knowledge can limit your ability to be objective. By recognizing this fact, you can listen more objectively.

Ridicule, sarcasm, vulgarity, and so forth, have no place in good communications. If you feel you need to speak loudly and resort to such language to get your point across or the job done, consider how adversely such action toward you affects your own feelings of importance and respect. When it becomes necessary to orally reprimand a subordinate, do it in private, keeping in mind that he/she is an individual and, as a petty officer, must have the respect of his/her subordinates. If a supervisor reprimands a person in public, both lose respect and are less effective in getting the job done.

PROFESSIONALISM

It is the responsibility of all senior petty officers to instill a spirit of professionalism in their subordinates. Ship maintenance is a complicated profession that leaves little room for error. Maintenance personnel who give less than undivided attention on a job present a potential hazard. Of primary importance are the ethical

attitudes and considerations involved in performing each maintenance task, the unspoken but carefully adhered to codes governing each person's action.

The responsible petty officer sets the example for others to follow, doing the right thing in carrying out each assignment. Undiluted professionalism means that there is no room for ethical lapses or occasional breaches of integrity on the part of supervisors or workers. The worker who even once shortcuts established procedures, does not follow maintenance manual instructions, sacrifices quality for speed, or performs any other action that could produce a negative judgment towards him/her lacks the professional integrity demanded in the Machinist's Mate rating. The supervisor who condones such action is equally guilty of a less than professional attitude and the results that such actions could cause.

There is no substitute for thorough knowledge of your ship, your job, and their associated procedures. Correct maintenance procedures and thorough quality assurance will almost always produce professional results. Ship safety demands pure, undiluted professionalism from all personnel involved in maintenance.

MAINTENANCE AND REPAIR RESPONSIBILITIES

To fulfill your administrative and supervisory responsibilities in connection with maintenance and repair, you must have the ability to plan ahead. During an average workday, occasions will arise when personnel have to leave their working spaces for one reason or another, thereby delaying the completion of scheduled work. Some delays can be anticipated; some cannot. Among the delays that can be anticipated are training lectures, immunizations, rating examinations, meals, and watches or other military duties.

Before making personnel work assignments, you should determine what delays can be anticipated. It may be possible to arrange assignments so that work interruption is held to a minimum. Whenever you estimate the completion time of a maintenance task, allow for these predictable delays.

Some engine-room maintenance and repair work just won't fit into a schedule but must be done whenever the opportunity arises. So, in addition to having the ability to plan, you must have a certain amount of flexibility so that you can alter your plans to fit the existing circumstances. A few administrative and supervisory considerations that apply particularly to maintenance and repair are noted in the following sections.

Materials and Repair Parts

The responsibility for maintaining adequate stocks of repair parts and repair materials belongs at least as much to you as it does to the supply department. The duties of the supply officer are to procure, receive, stow, issue, and account for most types of stores required for the support of the ship. However, the supply officer is not the prime user of repair parts and repair materials; the initiative for maintaining adequate stocks of repair materials, parts, and equipment must come from the personnel who are going to use such items.

The materials and repair parts to be used are specified for many repair jobs but not for all. When materials or parts are not identified in the instructions accompanying a job, you will have to do some research to find out what materials or parts should be used. When you must make the decision yourself, select materials on the basis of the service conditions they must withstand. Operating pressure and operating temperature are primary considerations in selecting materials and parts for most engine-room repair work. Special considerations may also apply; for example, high temperature steam piping must be made of material that has the property of creep resistance.

When materials and repair parts are not specified in the instructions accompanying a job, this does not always mean that you are free to use your own judgment. Instead, it may merely mean that you are expected to know where to look for information on the type of material or repair parts to be used. The shipboard sources of information that will be most helpful to you in identifying and selecting materials and repair parts include (1) nameplates on the equipment, (2) manufacturers' technical manuals and catalogs, (3) stock cards maintained by the supply officer, (4) ships' plans, blueprints, and other drawings, and (5) allowance lists.

NAMEPLATES on equipment supply information regarding the characteristics of the equipment and are therefore a useful source of information concerning the equipment itself. Nameplate data seldom, if ever, includes the exact materials required for repairs; however, the information given on the characteristics of the equipment and on pressure and temperature limitations may provide useful clues for the selection of materials.

MANUFACTURERS' TECHNICAL MANUALS are furnished with all machinery and equipment aboard ship. Materials and repair parts are sometimes described in the text of these technical manuals; more commonly, however, details of materials and parts are given on the drawings. MANUFACTURERS' CATALOGS of repair parts are also furnished with some shipboard equipment; when available, these catalogs are a valuable source of information on repair parts and materials.

The set of STOCK CARDS that is maintained by the supply officer is often a useful source of information on repair materials and repair parts. One stock card is maintained for each type of machinery repair part carried on board.

SHIPS' PLANS, BLUEPRINTS, and OTHER DRAWINGS available on board ship are excellent sources of information on materials and parts to be used in making various repairs. Many of these plans and blueprints are furnished in the regular large sizes; but microfilm is being used increasingly for these drawings. Information obtained from plans, blueprints, and other drawings should always be checked against the information given on the ship's COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL) to be sure that any changes made since the original installation have been noted on the drawings.

The COSAL for each ship is a basic source of information on repair parts and materials. The COSAL gives nomenclature and federal stock numbers for all hull, machinery, electrical, ordnance, and electronics materials.

Whenever you find it necessary to request materials or repair parts, remember two things:

1. If at all possible, find the correct federal stock number for each item requested. All materials now in the supply system have been assigned federal stock numbers. You should be able to locate them by using the COSAL and the other sources of information available to you.

2. Work informally with the supply department personnel who are actually responsible for identifying and requisitioning material. You have the technical knowledge, and you know what you need. If you cannot find the correct stock number, however, provide enough standard identification information so that supply personnel on board ship or ashore can identify the item you want. Experienced supply personnel are familiar with identification publications and can help you to locate the correct stock numbers and other important identifying information.

Repairable Items

As equipment and systems in the Navy grow more complex and more difficult to maintain at operating level, increasing use is being made of replacement equipment, components, or modules. These recoverable items or repairables, as they are called, are components of a system or equipment (for example, electronic control box, oxygen generator) or end items such as a governor or portable pump which are replaced periodically or upon failure and can be economically restored to a serviceable condition. When the technician removes the failed repairable, he/she draws a serviceable one to replace it and turns the failed item in for repair. This returned material, through repair and rework, then becomes an additional source of supply to the inventory manager. The decision that an item will be managed as a repairable is made by the materials systems commander or project manager concerned during the provisioning process.

Most repairables by their nature are mission essential items. In order to maintain an effective turn around time, a higher degree of control is required to manage this material, not only on the part of the inventory manager but also the fleet commanders-in-chief, fleet units, and commercial and Material Systems Command repair facilities. In addition, repairables are normally expensive and constitute a high cost inventory investment.

Scheduling Work

Careful planning is required to keep up with all engine-room maintenance and repair work. The following factors may be helpful in scheduling maintenance and repair work:

1. Size up each job before you let anyone start working on it. Check the applicable maintenance requirement cards so that you will know exactly what needs to be done. Also, check all applicable drawings.

2. Check on materials before you start. Be sure that all required materials are available before your personnel start working on any job. Do not overlook small items—nuts, bolts, washers, packing and gasket materials, tools, measuring devices, and so forth. You can save a good deal of labor by checking on the availability of materials before a job is actually started. An inoperable piece of machinery may be useless; but it can become a nuisance and a safety hazard, as well as useless, if it is spread around the engine room in bits and pieces while you wait for the arrival of repair parts or materials.

3. Check on the priority of the job and of all other work that needs to be done before you schedule any job.

4. When you assign work, give careful consideration to the capabilities and experience of your personnel. As a rule, the more complicated jobs should be given to the more skilled and more experienced individuals. When possible, however, the less experienced individuals should be given difficult work to do under supervision so that they may acquire skill in such jobs.

When you assign work, be sure that the person who is going to do a job is given as much information as necessary. An experienced worker may need only a drawing and a general statement concerning the nature of the job. A less experienced worker is likely to require additional instructions and, as a rule, closer supervision.

5. Keep track of the work as it is being done. In particular, check to be sure that proper materials and parts are being used, that the job is properly laid out or set up, that all tools and equipment are being used correctly, and that all safety precautions are being observed.

6. After a job has been completed, make a careful inspection to be sure that everything has been done correctly and that all final details have been taken care of. Check to be sure that any necessary records or reports have been prepared. Remember that job inspections can serve at least two very important purposes: first, to make sure that the work has been properly performed; and second, to increase the skill and knowledge of the person who has done the work. Do not overlook the training aspects of a job inspection. When your inspection of a completed job reveals any defects or flaws, be sure the worker understands what is wrong, why it is wrong, and how to avoid similar mistakes in the future.

Estimating Work

You will often be required to estimate the amount of time, the number of personnel, and the amount of material that will be required for repair jobs. Actually, you are making some kind of estimate every time you plan and start a repair job, as you consider such questions as How long will it take? Who can best do the job? How many workers will be needed? Are all necessary materials available?

However, there is one important difference and those that you make when your division officer asks for estimates. When you give an estimate to someone in authority over you, you cannot tell how far up the line this information will go. It is possible that an estimate you give to your division officer could ultimately affect the operational schedule of the ship; it is essential, therefore, that such estimates be as accurate as you can possibly make them.

Many of the factors that apply to the scheduling of all maintenance and repair work apply also to estimating the time that will be required for a particular repair job. You cannot make a reasonable estimate until you have sized up the job, checked on the availability of materials, checked on the availability of skilled personnel, and checked on the priority of the various jobs for which you are responsible. In order to make an accurate estimate of the time required to complete a specific repair job, you must also consider (1) what part of the work must be done by other shops, and (2) what kinds of interruptions and delays may occur. These factors are also important in the routine scheduling of maintenance and repair work, but they are particularly important when you are making estimates of time that may affect the operational schedule of the ship.

If part of the job must be done by other shops, you must consider not only the time actually required by these other shops but also the time that may be lost if one of them holds up your work. Each shop should make a separate estimate, and the estimates should be combined in order to obtain the final estimate. Do NOT attempt to estimate the time that will be required by other personnel. Attempting to estimate what someone else can do is risky because you can't possibly have enough information to make an accurate estimate.

Estimating the number of workers who will be required for a certain repair job is, obviously, closely related to estimating time. You will have to consider not only the nature of the job and the number of workers available but also the number of individuals who can work EFFECTIVELY on a job or on part of the job at the same time. On many jobs, there is a natural limit to the number of personnel who can work effectively at any one time. On a job of this kind, doubling the number of workers will not cut the time in half; instead, it will merely result in confusion and aimless milling around.

Perhaps the best way to estimate the time and the number of workers that will be required is to

that will have to be done, and then estimate the time and the workers required for each step.

Estimating the materials required for a repair job is often more difficult than estimating the time and labor required for the job. Although your own past experience will be your best guide for this kind of estimating, you should note the following general considerations:

1. Keep accurate records of all materials and tools used in any major repair job. These records serve two purposes: first, they provide a means of accounting for materials used; and second, they provide a guide for estimating materials that will be required for similar jobs in the future.
2. Before starting any repair job, plan the job carefully and in detail. Make full use of manufacturers' technical manuals, blueprints, drawings, and any other available information and try to find out in advance all the tools and materials that will be required for each step of the job.
3. Make a reasonable allowance for waste when you calculate the amount of material you will need.

TRAINING

By the time you reach the MM2 or MM1 level, you have acquired a great many practical skills and a large amount of theoretical knowledge. Among other things, you have learned a good deal about construction details, operating principles, and operating characteristics of all types of naval propulsion plants and associated engine-room auxiliary machinery; propulsion plant layout and piping system arrangement; principles of steam engineering, including theory of combustion, theory of energy transformations, and factors governing engine-room and fireroom efficiency; nature and theory of engine-room operations; operational troubleshooting; engineering casualty control; engine-room maintenance and repair; characteristics of metals and alloys; tests and inspections of main engines; characteristics and tests of lube oil; and records, reports, and other administrative requirements.

Being well versed in your field may make you a good Machinist's Mate, but it will not necessarily make you an effective Machinist's Mate. To be effective, you must be able to instruct subordinates in the skills and knowledges of the Machinist's Mate rating.

You will find excellent general information on how to plan, carry out, and evaluate an instructional program in the *Manual of Navy Instructors* and in the military requirements manuals for PO2, PO1, and CPO. The present discussion does not include basic information of the type given in these references; instead, it deals with some of the difficulties peculiar to the training of engine-room personnel and some of the ways in which you can overcome or minimize these difficulties.

Training of personnel is a necessary function and one of the most important responsibilities of senior petty officers. A Chief Machinist's Mate and, to some extent, a First Class will have regular and continuing responsibilities for the training of others. Even a supervisor fortunate enough to have a group of workers who are highly skilled and well trained will find that training is still necessary. For example, the training of strikers and lower-rated personnel for advancement examinations is a continuing, never-ending process. The Navy rotation policy being what it is, the best workers will eventually be transferred and replacements will, in most instances, require training before they can be relied on to take their places as effective members of the organization. These and similar problems require the division supervisor to be well versed in the aspects of training from using existing training materials effectively to setting up an effective training program.

SETTING UP A TRAINING PROGRAM

Setting up a training program involves such considerations as planning lessons and job plans, selecting and qualifying instructors, making arrangements for classroom space, phasing the training program with the scheduled workload, procuring visual and other training aids, and determining teaching methods for each lesson or lesson series.

Subject matter areas to be included in the training program include (1) maintenance of equipment supported by Machinist's Mates, (2) potential advancement examination topics, and (3) safety. In most cases, lessons will fall under more than one of the subject areas.

Once you have determined what publications will adequately cover the subject areas, you must divide the material into lessons and prepare lesson guides.

Number the lectures to provide a means of recording each person's progress in his/her individual training folder. Prepare a training syllabus sheet for each person in the division to

provide a handy index to the state of training of the division personnel as a whole.

Whether you teach the lessons yourself or assign other petty officers to conduct them depends on the state of training of your first and second class petty officers. All candidates for advancement to petty officer second class must complete and pass the nonresident career course based on *Military Requirements for Petty Officer Second Class.* This course sets forth some of the basic principles of training in general and teaching in particular.

Candidates for advancement to petty officer first class and chief petty officer must complete and pass the nonresident career course based on their appropriate military requirements manual. This course expands and amplifies training theory and introduces job analyses, training aids, and testing. For the first time in his/her career the prospective First Class Machinist's Mate is required to demonstrate his/her ability to formally teach, use various training aids, and prepare and administer written tests. In order to demonstrate correct instructional techniques, you may elect to teach certain lessons yourself or assign them to a competent instructor for the same purpose. Later you may assign less proficient petty officers as instructors so they may acquire the experience necessary for completing their practical factors for advancement.

If at all possible, conduct training sessions at the same time of day and on a regular schedule. Factors you should consider when scheduling lessons are usual meal hours, watches, availability of a classroom, and work schedules.

Some lessons are better suited for one type of instructional technique than others. Plan the type of presentation for each lesson well in advance. This will enable you to rotate the lessons among the petty officers who require experience in teaching.

The effectiveness of Machinist's Mate technical training is greatly enhanced by the use of training aids. You should always be on the alert for scrap material that can be converted to training aids with minimum expense. You must be aware of the existence of applicable training films. If they are available, try to schedule them for showing in conjunction with specific lessons.

When you plan a training program, decide where the classroom sessions should be conducted. The space you select should be in a quiet area or at least one with a minimum of noisy distractions. The area should be large enough to accommodate the expected student load, should be lighted, and should have adequate ventilation to keep the students awake and interested in the presentation. Convenience is another factor in the selection of classroom space. The characteristics mentioned above are all desirable. However, you may have to sacrifice one or more of them if you decide that a lesson should be taught in or near a working space.

TRAINING PROCEDURES

Training procedures are of two general types—formal and informal.

Formal training is conducted in the classroom through lectures, supplemented by required reading, and implemented by the use of all available visual aids. The training officer periodically prepares and publishes a training schedule. It lists the time of the training, the location of the classroom, the names of personnel who are to attend, the subject of the lesson, and the name of the instructor.

The division officer and qualified chief or first class petty officers prepare the lesson guides. The lesson guides should contain the title, learning objective(s), the time required to present the lesson, a list of instructional aids, a list of references, an outline for presentation, and a summary of the lesson.

When a petty officer has been assigned to instruct a given lesson, it is his/her responsibility to procure a copy of the lesson guide and from it prepare a lesson plan. Each instructor prepares lesson plans based on the lesson guide; and though the lesson plans may differ from instructor to instructor, they must adequately cover the subject.

Informal training is the practical instruction of personnel in the performance of maintenance tasks through demonstration and imitation under personal supervision in the engine room or shop. Nearly every maintenance task that is undertaken presents an opportunity for on-the-job training. The experienced members of the division should be used as fully as possible in demonstrating and imparting their skills to the less experienced.

Under this system, the trainee has the opportunity to actually do the job under the supervision of an experienced petty officer. The only equipment necessary is the job itself. It is necessary, of course, that the instructor have an interest in the job and the skill to do it well. The striker or trainee will learn by seeing the job performed and will gain experience by having a chance to participate in the accomplishment of the job.

The nature of informal training, conducted at every opportunity, makes regular scheduling impracticable. Nevertheless, informal training is still supported by a training syllabus. This syllabus is prepared under the guidance of the training officer, with content and scope corresponding to practical factor requirements of the personnel. The leading petty officer instructors and supervisors report the status of on-the-job training to the division officers at regular intervals so that a close watch may be made on individual progress. The records are kept for review by higher authority and can be used to indicate the need for training in special areas as well as for certain practical factors. The degree of success in on-the-job training depends on how well each individual imparts his/her skills and knowledge to the shipmate who is trying to learn.

Training Documentation and Recordkeeping

The individual Training Syllabus Sheet provides a record of formal lectures each member of a division attends. As a supervisor, you should make a report of practical training (OJT) to the division officer at regular intervals. This will indicate to the division officer when an individual has fulfilled a satisfactory level of skill to justify completion of the various items listed on the practical factors for advancement sheet. The formal training syllabus record and the record of practical training will indicate that required training has been completed in all areas or that a need for special training exists and further certifies when the individual may be considered qualified for advancement.

Personnel Qualification Standards

Personnel Qualification Standards (PQS) provide guidelines in preparing for advancement and for qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the "Quals" Manual.

The Quals and Record of Practical Factors are stated in broad terms. Each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (within the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific engineering system and/or individual systems of components.

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series—Theory

200 Series—Systems

300 Series—Watch Stations (duties, assignments, or responsibilities)

400 Series—Qualification cards

The introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as how to use it.

The Theory (100 series) section specifies the theory background required for an individual to begin study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watch Station (300 series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to

put this knowledge to use or to cope with maintaining the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures that could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, and so forth.

The 400 series section consists of the qualification cards. These cards are the accounting documents used to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard will depend on his/her assignment within an activity. The complete PQS is given to the individual being qualified so that he/she can use it at every opportunity to become fully qualified in all areas of the rating and of the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, and the maintenance officer as required to certify proper qualification. The completion of part or all of the PQS provides a basis for the supervising petty officer and officer to certify completion of Practical Factors for Advancement.

Engineering Operational Sequencing System

The many types of engineering plants that exist in today's modern Navy require an ever increasing range and depth of operational knowledge by engineering personnel at all levels of shipboard operations. The Engineering Operational Sequencing System (EOSS) provides each of these levels with the required information to enable the engineering plant to respond to any demands placed upon it that are within its design capability.

The Engineering Operational Sequencing System is a set of systematic and detailed written procedures, using charges, instructions, and diagrams, which provide the information required for the operation and casualty control functions of a specific shipboard propulsion plant.

The system will improve the operational readiness of the ship's engineering plant by increasing its operational efficiency, providing better engineering plant control, reducing operational casualties, and extending equipment life. The EOSS defines the levels of control and operation within the engineering plant and provides each supervisor and operator with the necessary information, in easily understood words, about each watch station. The EOSS is composed of three basic parts:

1. The USER'S GUIDE, installed with each system, is a booklet that explains the EOSS package and how it is used to the ship's best advantage. It contains samples of the various system documents and explains how they are used. Recommendations on how to introduce the EOSS system and how to train the ship's personnel in the use of these procedures for the system installed aboard ship are also included.
2. The ENGINEERING OPERATIONAL PROCEDURES contain all the information necessary to operate the ship's engineering plant properly. They also aid in scheduling, controlling, and directing plant evolutions from receiving shore service to underway and back down.
3. The ENGINEERING OPERATIONAL CASUALTY CONTROL contains information about recognizing certain symptoms of a casualty and the probable causes and effects of each casualty. It also contains information on preventive action that may be taken to preclude a casualty as well as procedures for controlling single source and multiple (cascade effect) casualties.

INSPECTIONS

The Chief of Naval Operations and the type commanders require that certain engineering inspections and trials be conducted in order to determine that required standards are being maintained and to accurately evaluate the operational readiness of the ship. The frequency with which the various types of inspections are held is determined by CNO, the fleet commander, and the type commander. As far as the ship is concerned, the type commander usually designates the kind of inspection and when it will be held.

A ship is frequently notified some time in advance when an inspection will take place, but preparation for an inspection should not be postponed until the notice of inspection is received. It is a mistake to think that a poorly administered division or department can, by a sudden burst of energy, be prepared to meet the inspector's eagle eye. By using proper procedures and keeping up to date on such items as repair

work, maintenance work, operating procedures, training of personnel, engineering casualty control drills, maintenance records, operating records, and other records and reports, you will always be ready for an inspection.

Your ship may be required to furnish the party that will make an inspection on another ship. Should this occur, you as a CPO or PO1 may be assigned as an assistant inspector. Therefore, you should know something about the different types of inspections and how they are conducted.

ADMINISTRATIVE INSPECTION

Administrative inspections cover administrative methods and procedures normally used by the ship. Each inspection is divided into two general categories—the general administration of the ship as a whole and the administration of each department. In this discussion we will consider the engineering department only.

The purpose of the administrative inspection is to determine (1) that the department is being administered in an intelligent, sound, and efficient manner, and (2) that the organizational and administrative methods and procedures are directed toward the objective of every naval ship—namely, being prepared to carry out her intended mission.

General Inspection of the Ship

Items of this inspection that will have a direct bearing on the engineering department, and for which the report of inspection indicates a grade, are as follows:

1. Appearance, bearing, and smartness of personnel
2. Cleanliness, sanitation, smartness, and appearance of the ship as a whole
3. Adequacy and condition of clothing and equipment of personnel
4. General knowledge of personnel in regard to the ship's organization, ship's orders, and administrative procedures
5. Dissemination of all necessary information among the personnel
6. Indoctrination of newly reported personnel
7. General educational facilities for individuals
8. Comfort and conveniences of living spaces, including adequacy of light, heat, ventilation, and fresh water, with due regard for economy

Engineering Department Inspection

The administrative inspection is primarily an inspection of the engineering department paper work, which includes numerous publications, bills, files, books, records, and logs. However, the inspection will also include other items with which the chief and first class will be concerned. Some of these items are the cleanliness and preservation of machinery and engineering spaces; training of personnel; assignment of personnel to watches and duties; proper posting of operating instructions and safety precautions; adequacy of warning signs and guards; marking and labeling of lines and valves; and proper maintenance of operating logs.

OPERATIONAL READINESS INSPECTION

The operational readiness inspection (ORI) is conducted to evaluate the offensive and defensive capabilities of the ship based on the state of training of the crew and the material condition of the ship.

The inspection will consist of the conduct of a battle problem and other operational exercises. A great deal of emphasis is placed on gunnery, damage control, engineering casualty control, and other appropriate exercises. Various drills are held and observed. The ship will be operated at full power for a brief period of time.

The overall criteria of performance include the following:

1. Can the ship as a whole carry out her operational functions?
2. Is the ship's company well trained, well instructed, competent, and skillful in all phases of the evolutions?
3. Is the ship's company stationed according to the ship's Battle Bill, and does the Battle Bill meet wartime requirements?

Observing Party

The personnel and organization of the operational readiness observing party will be about the same as that of the administrative inspection party. However, more personnel are usually required in the operational readiness observing party, and these additional personnel are very often chiefs and first class petty officers.

The observing party members should be briefed in advance of the scheduled exercises and

drills that are to be conducted. The observers must have sufficient training and exercise so that they can properly evaluate the exercises and drills that are to be held. Each observer will usually have an assigned station. He/she should be well qualified in the procedure of conducting drills and exercises for that station. It is highly desirable that each observer be familiar with the type of ship to be inspected.

Battle Problem

The primary purpose of a shipboard battle problem is to provide a medium for testing and evaluating the ability of all divisions and departments to function together as a team in simulated combat operations in order to accomplish the mission assigned by the problem.

Battle problems can be made the most profitable and significant of all peacetime training experiences since they demonstrate how ready a department is for combat. The degree of realism of this task governs its value: the more nearly it approximates actual battle conditions, the more valuable it is.

The degree of perfection achieved in any battle problem is a direct reflection of the skill and application of those who prepare it. A great deal depends upon the experience of officers and chief petty officers.

BOARD OF INSPECTION AND SURVEY INSPECTION

The Board of Inspection and Survey is under the administration of the CNO. This board consists of a flag officer, as president, and other senior officers necessary to assist him/her in carrying out the duties of the board. Regional boards and subboards are established, as necessary, to assist the Board of Inspection and Survey in the performance of its duties. In this discussion we are considering the shipboard inspections made by the subboards. These subboards consist of the chief inspector and about 10 or more members, depending upon the type of ship to be inspected.

The inspection made by the Board of Inspection and Survey is in several respects similar to the Material Inspection that has just been discussed. In fact, the Board of Inspection and Survey's inspection procedure, condition sheets, and reports are used as guides in establishing directives for the Material Inspection. The primary difference, in regard to material inspections, is that the Material Inspection is conducted by Forces Afloat, usually a sister ship, and the Board of Inspection and Survey inspection is conducted by a specially appointed board. This distinction, however, refers only to the routine shipboard material inspection. The Board of Inspection and Survey also conducts other types of inspections of a different nature.

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by the CNO, to determine the ships' material condition. This inspection usually takes place 4 to 6 months prior to regular overhaul. Whenever practicable, such inspections are held sufficiently in advance of a regular overhaul of the ship to permit completion, during such overhaul, of the authorized work resulting from the board's recommendations. Upon the completion of its inspection the board will report the general condition of the ship and its suitability for further naval service together with a list of the repairs, alterations, and design changes that in its opinion, should be made.

PROPULSION EXAMINATION BOARD

Propulsion examination boards (PEBs) have been established to ensure strict adherence to propulsion plant readiness standards and to ensure that their plants are operating properly and safely. The responsibility of the PEB is to

1. evaluate qualification levels of all propulsion plant personnel by applying appropriate engineering personnel qualification standards;
2. witness and evaluate the conduct of propulsion plant evolutions using the installed EOSS as a basic guide;
3. inspect the material condition of the propulsion plant to ascertain its state of operational readiness, preservation, and cleanliness; and
4. review and evaluate the administration of the ship's engineering department and the completeness and accuracy of all ship records relating to the propulsion plant.

The PEB will conduct two types of examinations: initial light-off examination (LOE) and operational propulsion plant examination (OPPE). LOEs are conducted under any of the following circumstances:

1. Before lighting the first fire in any boiler
2. Following major conversion of a ship

3. On a ship qualifying for fitting-out availability
4. On a ship with restricted availability in excess of 4 months

An OPPE is conducted under any of the following circumstances:

1. Within 6 months after the end of a regular overhaul
2. On a ship with restricted availability in excess of 4 months
3. On a ship undergoing major conversion

The current interval between subsequent examinations is approximately 18 months.

The PEB ascertains the state of training of propulsion plant personnel, the adequacy of administrative procedures, and the material readiness of the propulsion plant machinery spaces. Propulsion plant drills are required only for the OPPE; harder, walk-through drills may be conducted at the discretion of the senior PEB member during an LOE.

Upon the conclusion of each examination, the senior board member will submit by message the results of the examination to the respective fleet commander-in-chief. The overall evaluation of the propulsion plant readiness will be described as either satisfactory or unsatisfactory.

- A ship found satisfactory is ready for unrestricted operations or for light-off.

- A ship found unsatisfactory as a result of an LOE must be reexamined by the PEB and found satisfactory before the plant is lighted-off.

- A ship found unsatisfactory as a result of an OPPE must have approval of the cognizant fleet commander-in-chief before the plant is lighted-off and must pass a reexamination by the PEB before the propulsion plant is returned to unrestricted or limited status.

SHIP TRIALS

There are a number of different types of trials that are carried out under specific conditions. To convey a general idea of the different trials, a list comprising most of them is given here:

1. Builder's trials
2. Acceptance trials
3. Final contract trials
4. Post-repair trials
5. Pre-overhaul trials
6. Recommissioning trials
7. Full-power trials
8. Economy trials

The purpose of trials is to demonstrate operability, performance, endurance, and economy as required. The trials that are considered to be routine and the ones that will be discussed in this chapter are the full-power, economy, and post-repair trials. Information on the other types of trials can be found in chapter 094 of the *Naval Ships' Technical Manual.*

POST-REPAIR TRIAL

The post-repair trial should be made whenever the machinery of a vessel has undergone extensive overhaul, repair, or alteration that may affect the power or capabilities of the ship or the machinery. A post-repair trial is usually made when the ship has completed a routine naval shipyard overhaul period; the trial is OPTIONAL whenever machinery has undergone only partial overhaul or repair. The object of this trial is to ascertain if the work has been completed satisfactorily and performed efficiently, and if all parts of the machinery are in every respect ready for service.

The post-repair trial should be held as soon as practicable after the repair work has been completed and the preliminary dock trial made, and when the persons responsible for the work are satisfied that the machinery is in all respects ready for a full-power trial. The conditions of the trial will be largely determined by the character of the work that has been performed. The trial should be conducted as the CO and the commander of the shipyard direct. In cases where repairs have been slight and the CO is satisfied that they have been performed satisfactorily and can be tested sufficiently without a full-power trial, the ship may proceed without a trial.

Any unsatisfactory conditions beyond the repair capacity of the ship's force should be corrected by the naval shipyard. If necessary, machinery should be opened up and carefully inspected to determine the extent of any damage, defect, or maladjustment that may have appeared during the post-repair trial.

A certain number of naval shipyard personnel—technicians, inspectors, and repairmen—accompany the ship on a post-repair trial. The yard personnel witness the operation of machinery that has been overhauled by the yard. If a unit of machinery is not operating properly, the yard

technicians will carefully inspect it and try to determine the cause of unsatisfactory operation.

FULL-POWER AND ECONOMY TRIALS

Trials are necessary to test engineering readiness for war. Except while authorized to disable or partially disable, ships are expected to be able to conduct prescribed trials at any time. Ships normally are provided approximately a 2-week period, after tender overhaul and a 1-month period after shipyard overhaul to conduct final checks, tests, and adjustments of machinery before being called upon to conduct a competitive trial.

Trials are also held from time to time to determine machinery efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs, and the most economical rate of performance under various conditions of service.

The full-power and economy trials, as discussed in this chapter, are considered to be competitive trials. It is assumed that the ship has been in full operational status for sufficient time to be in a good material condition and to have a well-trained crew.

Prior to the full-power trial, inspections and tests of machinery and equipment should be made to ensure that no material item will interfere with the successful operation of the ship at full power. The extent of the inspections and the tests will largely depend upon the recent performance of the ship at high speeds, the material condition of the ship, and the time limits imposed by operational commitments.

Not later than one day before a trial, the engineering officer should report to the CO the condition of the machinery installation, identifying both equipment that is ready for trial and equipment that may not be ready or may not be safe.

The following general rules should be observed during all full-power trials and as appropriate during other machinery trials:

1. The speed of the engines should be gradually increased to the speed specified for the trial. Prior to commencing a full-power trial, the machinery should be thoroughly warmed up; this can be done by operating at a high fractional power.
2. The machinery should be operated economically. Designed pressures, temperatures, and number of revolutions must not be exceeded.
3. The full-power trial should not be conducted in SHALLOW WATER, which may cause excessive vibration, loss of speed, and overloading of the propulsion plant.
4. If it is desirable to continue a full-power trial beyond the length of time originally specified, the observations should be continued until the trial is finished. The trial should be continuous and without interruption. If a trial at constant rpm is discontinued for any reason, that trial should be considered unsatisfactory and a new start should be made. No major changes of the plant setup or arrangement should be made during economy trials.

Reports of trials should include all the attending circumstances, especially draft forward, draft aft, mean draft, and corresponding displacement of the ship at the middle of the trial; the condition of the ship's bottom; the last time drydocked; the average horsepower developed by the main engines; the consumption of fuel per hour, per mile, and per shaft horsepower on indicated horsepower of the main engines per hour; the average speed of the ship through the water; and the average revolutions of the propelling engines. The methods by which the speed and shaft horsepower were determined should also be described.

This report should also include a tabulation of gauge and thermometer readings of the machinery in use, and revolutions or strokes of pertinent auxiliaries. The auxiliaries in use during the trial should be stated. The report should state whether the machinery is in a satisfactory condition. If its condition is found to be unsatisfactory, all deficiencies should be fully described and recommendations made for correcting them.

RECORDS AND REPORTS

Engineering records and reports for the administration, maintenance, and repair of naval ships are prescribed by directives from authorities such as the type commander, NAVSEA, and the CNO. These records and reports must be accurate and adequate, and must be kept up to date according to current instructions.

As an MM3 and MM2, you have been primarily concerned with operating logs and similar records. As an MM1 and MMC, you will have new supervisory duties that will require that you have a greater knowledge of engineering paper work and the associated administrative procedures. Supervisory duties and responsibilities

require a knowledge of engineering records as well as of such items as inspections, administrative procedures, training, preventive maintenance, and repair procedures.

The Engineering Log and the Engineer's Bell Book are the only legal records compiled by the engineering department. The Engineering Log is a midnight-to-midnight record of the ship's engineering department. The Engineer's Bell Book is a legal record of any order regarding change in the movement of the propellers.

ENGINEERING LOG

The Engineering Log is a complete daily record, by watches, of important events and data pertaining to the engineering department and the operation of the ship's propulsion plant. The log must show the following information:

1. Total engine miles steamed for the day
2. Draft and displacement upon getting underway and anchoring
3. The engines, boilers, and principal auxiliaries in use and any changes to this equipment
4. Any injuries to engineering department personnel
5. Any casualties to machinery, equipment, or materials
6. Any other matters specified by competent authority

Entries in the Engineering Log must be made according to instructions given in (1) 3120/2D, (2) *Naval Ships' Technical Manual,* chapter 090, and (3) directives issued by type commanders.

The Engineering Log is a legal record. It should be prepared and signed by the engineering officer of the watch (EOOW) underway or the duty engineer in port. No erasures are permitted in the log. When a correction is necessary, draw a single line through the original entry so that the entry remains legible, then initial the margin of the page.

The engineering officer verifies the accuracy and completeness of all entries and signs the log daily. The commanding officer approves the log and signs it on the last day of each month and on the day he/she relinquishes command.

ENGINEER'S BELL BOOK

The Engineer's Bell Book, NAVSHIPS 3120/1, is a record of all bells, signals, and other orders received by the throttleman regarding movement of the ship's propellers. The throttleman or an assistant enters each order into the Bell Book as soon as it is received. Entries are usually made by an assistant when the ship is entering or leaving port, or engaging in any maneuver that is likely to involve numerous or rapid speed changes. This procedure allows the throttleman to devote his/her undivided attention to answering the signals.

Before going off watch, the engineering officer of the watch signs the Bell Book on the line following the last entry for his/her watch, and the next officer of the watch continues the record immediately thereafter. In machinery spaces where an engineering officer of the watch is not stationed, the bell sheet is signed by the watch supervisor. (Note: A common practice is also to have the throttleman sign the Bell Book prior to the EOOW or his/her relief.)

The Bell Book is maintained by bridge personnel in ships and craft equipped with controllable reversible pitch propellers when the engines are directly controlled from the bridge. When control is shifted to the engine room, however, the Bell Book is maintained by the engine-room personnel. The last entry made in the Bell Book on the bridge indicates the time that control is shifted and the first entry made in the Bell Book in the engine room indicates the time that control is taken by the engine room. Similarly, the last entry made by engine-room personnel indicates when control is shifted to the bridge. When the Bell Book is maintained by bridge personnel, it is signed by the OOD in the same manner as prescribed for the engineering officer of the watch.

Alterations or erasures are not permitted in the Bell Book. An incorrect entry is corrected by drawing a single line through the entry and recording the correct entry on the following line. Deleted entries are initialed by the engineering officer of the watch, the OOD, or the watch supervisor, as appropriate.

ENGINEERING PROGRAMS

For several years significant losses of dollars and man-hours have resulted from injuries, illnesses, and property damage attributed to workplace hazards. It is essential that all naval personnel strive to eliminate or control all identified hazards as best they can within their capabilities. In the remainder of this chapter we

will discuss some of the programs designed to reduce equipment downtime and to protect personnel during operation and maintenance.

EQUIPMENT TAG-OUT

The tag-out program provides a procedure to be used when a component, a piece of equipment, a portion of a system, or a system, must be isolated because of some abnormal condition. It also provides a procedure to be used when an instrument becomes unreliable or is not operating properly. A tag-out procedure is necessary because of the complexity of modern ships and the costs, delays, and hazards to personnel that can result from the improper operation of equipment.

There are two types of tag-outs used, one for equipment and another for instruments. The major difference is that labels (either out-of-calibration or out-of-commission) are used for instruments, and tags (either danger or caution) are used for equipment. A tag-out log is maintained as a record of authorization of each effective tag-out action.

Tag-out procedures represent the minimum requirements for tag-out. These procedures are mandatory and are standardized aboard ship and at repair activities. These procedures are described in OPNAVINST 3120.32A.

MEASURE PROGRAM

All equipment requiring calibration and/or servicing should be maintained at maximum dependability. To meet this need, the Chief of Naval Material implemented the Metrology Automated System for Uniform Recall and Reporting (MEASURE). In this section, we will discuss some of the major parts of the MEASURE system.

Meter Card

The METER card is a five-part, color-coded form to which the equipment identification and receipt tag is attached. It is filled out by either the customer or the calibrating activity. You will have a meter card for every item aboard ship that requires calibration.

This card is used to record a calibration action, to add or delete items from inventory, to reschedule calibration, to transfer custody, or to record man-hours for a completed calibration.

The white copy of a completed meter card is sent to the Measure Operational Control Center (MOCC), where the information is entered into a computer to update the measure data base. The new information is then printed on another meter card and sent back to the customer activity to be used the next time another transaction is to be completed. Accurate data, completeness, and legibility in filling out the meter card are essential. Remember a computer CANNOT think.

Format 310

This format is sent to you every month and is an inventory of all your items, including overdue and delayed items. All additions, deletions, and corrections to this format are submitted to the MOCC on either the meter card or on the add-on inventory form.

Format 350

This format is also distributed monthly and is for informational purposes. It is prepared in a customer/subcustodian sequence to readily identify all items held on subcustodian basis by other activities. This format is produced concurrently with format 310. Both format 310 and 350 will have the last calibration dates of all items and the due dates of their next calibrations.

Format 802

Format 802 is a recall schedule. It is updated and distributed monthly. It tells you what equipment is due for calibration that month. It is sequenced by customer activity, by subcustodian, and by calibration laboratory.

The MEASURE system is a tool for your use. It is only as good as the information that is put into it. Remember information MUST be legible, accurate, and consistent.

LUBE-OIL MANAGEMENT

The lube-oil management program is used aboard ship to prevent lubrication-related casualties to machinery. Oil changes are necessary to ensure that a sufficient quantity of good quality lube oil is maintained in each piece of machinery at all times. Oil change guidelines vary depending on the type of machinery and the quality of the lube oil as determined by ship and shore base testing.

The major points covered by the lube-oil management program instructions are as follows:

1. Frequency of taking lube oil samples

2. Type of equipment from which samples are taken
3. Required logs and records
4. Type of required testing or oil samples
5. Required action based on results of tests

You should become familiar with the steps and procedures of the lube-oil management program. A properly applied lube-oil management program will significantly reduce downtime of machinery caused by oil-related failures.

WATER CHEMISTRY

Shipboard water chemistry controls requirements for propulsion and auxiliary steam generating systems. Effective steam plant water chemistry control requires an understanding of the shipboard water cycle, the importance of good quality feedwater, and the ultimate damage that feedwater contaminants cause to boiler watersides and steamsides. Equally important is the development of an appreciation for the principles that govern the boiler water and feedwater treatments designed to prevent scale, corrosion, and carryover. Propulsion plant water chemistry control is vital to prevent damage to boilers and other plant components by corrosion, fouling of heat transfer surfaces, and carryover of water with steam.

As an MM1 or MMC you must be familiar with boiler water/feedwater test and treatment procedures. For any information concerning boiler water/feedwater test and treatment refer to *Naval Ships' Technical Manual,* chapter 220, volume 2.

HEARING CONSERVATION PROGRAM

The purpose of the Navy hearing conservation program is to prevent occupational noise-related hearing loss among Navy personnel. The program includes, as a minimum, the following requirements:

- Work environments must be surveyed to identify potentially hazardous noise levels and personnel at risk

- Environments that contain or equipment that produces potentially hazardous noise should, whenever feasible, be modified to reduce the noise level to acceptable levels. If modifications are not feasible, personnel working in the environment or near the equipment must use approved hearing protection devices.

- Periodic hearing testing must be conducted to monitor the effectiveness of the hearing conservation program.

- All personnel subject to excessive noise levels must be made aware of the hearing conservation program and its requirements.

- The overall success of the program depends on continued emphasis and education.

Hearing loss has been and continues to be a source of concern within the Navy. The guidelines for an effective hearing conservation program are outlined in OPNAVINST 5100.23B.

HEAT STRESS PROGRAM

The overall purpose of the heat stress program is to provide shipboard working environments that, under normal operational conditions, do not expose personnel to excessive heat stress. Program publications provide policy and procedures for the control of personnel exposed to heat stress. They also list heat stress standards, describe typical heat stress related deficiencies found aboard ship, and specify actions ships' personnel must take to either correct or justify the existence of discrepancies.

As an engineering officer of the watch you must be familiar with this program. For further information on shipboard heat stress control, refer to OPNAVINST 5100.20C.

SUMMARY

This chapter has discussed many of the administrative responsibilities you will have as an MM1 or an MMC. The areas covered include administration and supervision of rate-related activities, training programs, material and operational inspections, and shipboard engineering programs. By becoming proficient in these responsibilities, you will increase your professional capabilities and will be better able to help ensure your ship's mission readiness.

CHAPTER 12

REPAIRS AND MATERIALS

Ships can operate only a certain length of time without repairs. To keep a ship in prime condition, constant attention should be given to material upkeep and appropriate intervals of time must be allotted for general overhaul and repair.

Even when regular preventive maintenance procedures are carefully followed, mishaps and malfunctions may necessitate emergency repair work. Defects and deficiencies that can be corrected by ship's force should be dealt with as soon as possible. When repairs are beyond the capacity of ship's force to accomplish, aid must be obtained from a repair activity afloat or ashore.

REPAIRS AND ALTERATIONS

Corrective maintenance to ships may be divided into the general categories of (1) repairs, (2) alterations, and (3) alterations equivalent to repairs.

A REPAIR is defined as the work necessary to restore a ship or ship system component condition without change in design, location, or relationship of parts. Repairs may be made by ship's force, by repair ships and tenders, or by naval shipyards or other shore-based activities.

An ALTERATION to a naval ship is any change in the hull, machinery, equipment, or fittings that involves a change in design, materials, number, location, or relationship of the component parts of an assembly regardless of whether it is undertaken separately from, incidental to, or in conjunction with repairs. Requests for alterations may originate with the Naval Sea Systems Command, the forces afloat, or the Chief of Naval Operations (CNO).

The Naval Sea Systems Command is responsible for administering ship's alterations under its technical control. Through its day-to-day relations with the forces afloat, the naval shipyards, private industry, and research centers, the Naval Sea Systems Command remains up to date on technical developments. In striving to maintain the ships of the fleet in as efficient and modern a state as possible, the Naval Sea Systems Command may determine that a particular ship or class of ship should be altered to include desired improvements. These alterations may be changes to the hull, such as changes to bulkheads that will strengthen them or changes to deck arrangements that will provide space for installation of machinery; changes to machinery or the substitution of newer and more efficient machinery; changes to equipment, such as the replacement of an item with a more efficient type; or changes in design, such as the installation of a paint mixing and issue room.

When the commanding officer of a ship considers an alteration necessary for the satisfactory performance of his ship, he addresses a request for the alteration to the Naval Sea Systems Command via the administrative chain of command. Copies of the request are sent to all ships of the type within the appropriate fleet for comments on applicability.

Another source of alteration is the reports of the Board of Inspection and Survey. Upon completion of each material inspection, the Board, in its report of the general condition of the ship and its suitability for further naval service, furnishes a list of repairs and alterations, which, in its opinion, should be made. Alterations recommended by the Board of Inspection and Survey normally are not acted upon by the Naval Sea Systems Command until after the receipt of appropriate requests from the commanding officers of the ships inspected and the recommendations of the type commanders.

Alteration requests addressed to the Naval Sea Systems Command are endorsed by the type commanders (or other administrative commanders, as appropriate), with their recommendations on approval, classification, and applicability to other ships of the type. Copies of the basic request and endorsements are forwarded to other type commanders concerned, who are also requested to comment on them

for the information of the Naval Sea Systems Command.

Previously, all alterations involving material under the technical control of the Naval Sea Systems Command were classified as either SHIPALTs or NAVALTs. Procedures for requesting ship modifications were complicated and time-consuming. Two recently developed programs sought to simplify the process and make the changes easier to control.

The SHIPALT Improvement Program reduced the number of SHIPALTs by increasing the control of the SHIPALT requesting, administration, and installation process.

The Machinery Alteration Program created a third category of alterations, machinery alterations (MACHALTs). This program was established to simplify the making of shipboard changes that are not as complicated, time-consuming, costly, and widespread among the fleet as SHIPALTs and NAVALTs. Machinery alterations involve changes to hull, machinery, and electrical (HM&E) equipment and systems where the changes are contained within the individual pieces of equipment or the system. The MACHALT program enables changes to be made more expeditiously and eliminates these simpler changes from the formal SHIPALT process. For detailed information concerning MACHALTs, refer to NAVSEA Instruction 4720.15.

SHIP AVAILABILITIES

As it applies to work on naval ships, an AVAILABILITY is the period of time assigned a ship by competent authority for the completion of repairs, alterations, and alterations equivalent to repairs at a repair activity.

During certain availabilities, if a ship is incapable of engaging in fleet operations, its operating schedule is adjusted accordingly. Only the authority granting the availability can alter or extend the period of the availability; however, a repair activity may request that the ship's availability be extended so that work can be completed or it may recommend a completion date to the authority granting the availability.

REPAIR SHIP/TENDER REPAIRS

Ships are scheduled for a regular tender availability or an upkeep period alongside repair ships or tenders at certain intervals of time. These time intervals vary with different types of ships. The availability periods are usually planned far in advance and depend upon the quarterly activity schedule of the ship concerned.

When a ship receives its activity schedule, or is otherwise notified, it can begin to prepare the necessary paper work in advance of the scheduled availability period. The maintenance deferred action sheet is used as a basis for advanced preparation of a work request.

The work requests are sent with a forwarding letter to the type commander. The staff officer handling material and maintenance screens the work requests. Most of the ship's availability work list items are approved and authorized. Also, the ship may have to furnish more detailed information on certain work requests. The amount of corrective action taken by the reviewing staff officer will depend upon how well the work requests are written and the extent to which they follow established policies and procedures. Upon the completion of this screening, the ship's work requests are forwarded to the repair ship or tender. This is done well in advance of the assigned period of availability so that the repair department personnel can schedule the work and make any necessary preparations.

WORK REQUESTS AND JOB ORDERS

Although the terms *work request* and *job order* are sometimes used interchangeably, this is not technically correct because the two terms actually have slightly different meanings. Work requests are made up by the ship and are forwarded through proper channels to the repair activity. When the work request has been approved by the repair activity, it is issued as a job order.

As soon as the work requests have been approved at the arrival conference, the jobs that require delivery to the tender should be started. Starting these repair jobs early is very important in getting all necessary jobs completed. Equipment that is not needed for the operation of the ship may be disassembled in advance so that the defective parts can be delivered to the tender as soon as the work requests have been approved.

All material delivered to the tender must be properly tagged and identified. The information on each tag should include the number and name of the ship; the department, division, or space; and the job order number. Additional information should be included if necessary. Reference material such as blueprints and manufacturer's

technical manuals should be identified with the ship's name and number.

Ship-to-Shop Jobs

Many repair jobs are designated by the ship or approved by the repair activity as "ship-to-shop" jobs. In a job of this type, ship's force does a large part of the repair work. For example, the repair or renewal of a damaged pump shaft might well be written up as a ship-to-shop job. The pump is disassembled and the shaft is removed by ship's force; the shaft and any necessary blueprints are delivered to the machine shop of the repair activity. The machine shop supervisor checks the job and gives an approximate date of completion. When the shaft has been repaired, or when a new one has been made, it is picked up and brought back to the ship by ship's force. The pump is reassembled, inspected, and tested by ship's force to ascertain that the unit is satisfactory.

Repair jobs on portable equipment, such as small gauges and valves, are almost always written up as ship-to-shop jobs.

Checking Progress of Tender Repair Jobs

The petty officer in charge should know at all times the status of repair work (including ship's force repair work) being done for his/her space or equipment.

Tender repairs that are being made on your own ship can be checked by discussing them with the petty officer in charge of the repair detail. Checking on the progress of work in the shops on the tender requires planning and coordination between your ship and the tender. Personnel in the tender shops are busy with their repair work, so any method used to check on the progress of work must be one that does not interfere with progress.

Some tenders and repair ships have a chief petty officer who acts as ship superintendent. The ship superintendent's duties include the following:

1. Acting as liaison officer between the ships alongside and the tender in regard to repair department jobs
2. Acting as a coordinator of shop work for assigned ships
3. Reporting daily to a representative of the ship
4. Maintaining a daily running progress report or chart that indicates the percentage of completion of each job; the availability of plans, manufacturers' technical manuals, samples, and so forth; and the availability of materials required for each job
5. Notifying the ship when it is time to pick up completed work from the tender
6. Notifying ship's personnel when it is necessary for them to witness tests needed because work has been performed on machinery, compartments, tanks, and so forth
7. Obtaining signatures from officers if job orders are cancelled or changed

If the tender provides a ship superintendent, it is obviously quite easy for ship's personnel to check on the progress of the work. If the services of a ship superintendent are not provided, the ship alongside the tender should appoint a petty officer to perform similar duties for the division or department.

A progress chart should be kept for all work that is planned for completion during the repair period. The chart should show the up-to-date status of each job. Keeping a close watch on the progress of the repair work will ensure that jobs are not unnecessarily delayed, that jobs are not overlooked or forgotten, and that all work undertaken is satisfactorily completed at the end of the repair period.

NAVAL SHIPYARD REPAIRS

The primary purpose of a naval shipyard is to render services to the fleet in the form of efficient and economical construction, repair, alteration, overhaul, docking conversion, outfitting, and replenishment and to perform related special manufacturing when required. Naval shipyards perform many other functions, including research and design, which are not discussed here.

Naval shipyards are designated as home yards and as planning yards. A home yard is the shipyard to which a particular ship is usually assigned for a regular overhaul. A planning yard is a shipyard designated by the Naval Sea Systems Command to undertake the design work for a particular type of ship.

WORK REQUESTS

The procedures for submitting shipyard work requests prior to a regular overhaul are

contained in the *Maintenance and Material Management (3-M) Manual.*

Type commanders require that work requests for work to be undertaken during a repair period (regular or interim) be submitted for them to inspect, screen, approve, and forward to the shipyard well in advance of the beginning of an overhaul. This is necessary in order to permit successful preliminary planning by the shipyard.

Aboard ship, each work request is submitted on the standard work request form. All work requests are screened and assigned a work priority at a conference of the heads of departments, the executive officer, and the commanding officer. A work list containing brief statements of the work to be accomplished, arranged in the ship's integrated priority sequence, is prepared and submitted along with the work requests to the type commander for his/her screening action.

ALTERATIONS

The type commander submits to NAVSEA annually the recommended ship alterations (SHIPALTs) to be considered for ships to be overhauled during the fiscal year. NAVSEA publishes, in the Fleet Modernization Program (FMP) reports, the SHIPALTs that are authorized.

Approximately 6 months prior to the beginning of a scheduled overhaul, the designated shipyard is given a NAVSEA 180-day letter, which identifies the specific work to be undertaken and grants funding for the overhaul. The 180-day letter provides the first details of work, other than that listed on a Planning and Engineering for Repairs and Alterations (PERA) report, to be undertaken during the yard period.

About 180 days prior to a regular overhaul, the type commander is provided with the priority listing of alterations to be made on the ship.

Approximately 90 days in advance of the ship's arrival, NAVSEA will forward to the shipyard, to the type commander, and to the ship a priority listing of approved alterations (90-day material status letter). Any changes in the scope of work authorized in the 180-day letter will be reflected in this letter.

SHIPALTs assigned to forces afloat are not, as a rule, undertaken by naval shipyards.

Naval Shipyard Arrival Conference

When the ship arrives at the shipyard for a routine overhaul, an arrival conference is held. The conference is supervised usually by the planning officer of the shipyard and attended by representatives from the ship, the type commander, and the naval shipyard planning department. The ship's work requests and the individual item costs estimated by the shipyard planning department are reviewed. When necessary, the details of the repair items are discussed, and the work to be done is decided upon.

The limitations of the funds made available by the type commander determine to a great extent the amount of repairs that will be completed during a naval shipyard repair period. The estimated cost of each repair job, when approved at the conference, is added up to give the total cost. When the total cost reaches approximately the amount of funds appropriated, or the cutoff point, the shipyard will not accept additional repair requests. Under this condition, when there are several additional important jobs that should be performed, the type commander must either furnish more funds or revise the priority list accordingly.

Establishing the cutoff point enables the shipyard to make certain that the most important repairs and alterations are completed during the availability period. This does not necessarily imply that other items with less urgent priority will not be undertaken and completed before the end of the overhaul period. After the ship has been placed in drydock, for example, workers may find that anticipated repairs to the shafting and propeller are not necessary, and the funds reserved for this work can be used to finance other items. Sometimes a job may be seriously underestimated because of conditions that were not apparent until the job was well underway. If the funds originally provided to cover the cost of the work are not sufficient, the necessary funds may have to be provided by deferring other approved items of less relative importance.

Also established at the arrival conference are tentative dates for drydocking, the operation of the propulsion machinery and associated auxiliary equipment, and dock and sea trials.

When agreement has been reached at the arrival conference on the items of work to be undertaken, the planning department issues job orders authorizing the work to be performed by the production ships. Each job order clearly defines the scope of the work, includes complete specifications, and identifies the necessary plans. Job orders are not issued for all work at the same time. The first to be issued are for those jobs requiring practically the entire availability period. The other orders are issued as soon as possible

thereafter. If design plans are required for any specific item, the issue date of the job order is coordinated with the planned completion date. In any case, job orders for all items approved at the arrival conference are usually issued during the first third of the overhaul period.

The method of numbering job orders differs somewhat in the several naval shipyards. However, the numbering systems are all for the purpose of identifying a particular item of work by a job order number. In addition to the naval shipyard job order number, the ship's work request or work item number is entered on the job order sheets for identification purposes.

Checking on Progress of Work

During a routine shipyard overhaul the ship must submit shipyard progress reports as required by the type commander's instructions. Supervisory personnel of the ship must therefore keep an accurate check on the progress of all work (including ship's force work) at all times. Standard progress charts are available for recording and reporting progress. As a rule, one progress chart is used to record shipyard repairs, another to record alterations, and another to record ship's force work. Copies of the progress charts should be posted outside the logroom and kept up to date by assigned ship's personnel.

The shipyard commander holds frequent (usually weekly) conferences with the commanding officer of the ship to review progress. The ship superintendent and other key shipyard personnel also attend these conferences.

In checking on the progress of work, it is of course necessary to know what repair work is planned for completion during the overhaul. This information can be obtained from the job orders issued by the planning department of the yard. The ship receives three or more copies of the job orders. A complete set of job orders is usually kept on file in the logroom; a set of the job orders that apply to your division is usually kept by your division officer. Always check the details of the job orders before you start checking on the progress of a repair job.

DRYDOCKING THE SHIP

The ship is drydocked each time it goes into a naval shipyard for a regular overhaul. Drydocking is usually scheduled as early as possible in the overhaul period, since it is difficult to tell in advance just how much drydock work will be required. Scheduling the drydocking for early in the overhaul permits all necessary drydock work to be done without interfering with work that must be done later and without interfering with machinery trials, strength tests of structural work, and so forth. As soon as all drydock work has been completed, the ship is removed from drydock.

Before the ship goes into drydock, ship's personnel must have detailed information on the sea valves. When preparing to drydock the ship, the engineer officer is required to furnish the shipyard with a sea valve checkoff list indicating the size, location, and function of each sea valve. The engineer officer must also furnish the yard with the ship's docking plan and, if the ship was last drydocked in a different shipyard, the last docking report. The shipyard maintains file copies of docking plans for each ship that it is expected to drydock. However, it is necessary to check these plans against the ship's copy to make any corrections reflecting work done elsewhere and to determine the last drydocking position used.

A ship entering drydock should be without list and without excessive trim. Trim in excess of 1 foot per 100 feet of length is sufficient to make the docking operation hazardous. If practicable, the trim should be brought below this limit before any attempt is made to drydock the ship.

While the ship is in drydock, no fuel oil, water, or other weight should be shifted, added, or removed, except as specifically authorized by the docking officer. Water tanks and oil tanks should be either completely full or completely empty, if practicable. When permission is given by the shipyard to shift weight, ship's force must keep accurate records of the amount of weight shifted, the location from which it is shifted, and its new location.

The propellers must not be turned without permission of the docking officer after the ship enters the dock. No fuel oil or other flammable liquid should be drained or pumped into the dock. If the need arises, the shipyard will provide special containers for the disposal of these liquids. During freezing weather, all valves, pipes, and fittings attached to the hull should be drained to prevent freezing and consequent cracking.

Whenever a ship is drydocked, propellers, shaft tubes, outboard portions of the shafting, couplings, bearings, and all sea valves must be examined and the results of the examination must be entered into the engineering log.

Examination of each sea valve should include determination of the condition of the yoke,

yoke rods, valve stem, securing bolts, and all internal parts of the valve. At least two of the bolts holding outboard valves to sea stools should be removed from each valve for inspection, and the remaining bolts should be sounded with a hammer. If defects are found in any bolt, all the other bolts for the valve should be removed for inspection. Whenever all bolts are removed, the gasket should be replaced. All repairs required to place the sea valves in good condition should be made while the ship is still in drydock.

While the ship is in drydock, ship's force and shipyard personnel may have occasion to work on sea valves. All openings in the hull must be blank-flanged at the end of working hours; ship's force and shipyard personnel are each responsible for closing the openings that they make in the hull. At the end of each working day, the status of all sea valves must be reported to the engineer officer and entered into the engineering log.

Before the drydock is flooded, all sea valves must be carefully inspected to be sure they are properly secured. The results of this inspection should be reported to the engineer officer and entered into the engineering log.

While the drydock is being flooded, there must be continuous inspection of all sea valves until the ship is afloat and all valves are under a normal head of water. Any unsatisfactory condition must be reported at once to the engineer officer so that the docking officer can be notified. A report of leakage must be made in sufficient time so that the docking officer can stop flooding, if necessary, before the ship lifts from the supporting blocks.

Shortly after the undocking of a ship, the shipyard submits the docking report to NAVSEA with copies to the commanding officer and the type commander. The docking report includes the name and class of ship; the place and date of docking and undocking; the number of days underway, not underway, and waterborne since the last docking; the formula for the paint used and the extent of bottom painting; the shaft and rudder clearances; the docking position used; and details of all other work performed.

DOCK TRIAL

A dock trial is always held after major repairs to propulsion machinery have been made by a naval shipyard. A dock trial is usually held at the completion of a routine naval shipyard overhaul.

At least one day prior to the dock trial, all auxiliary machinery should be tested to prevent delay or interference with the testing of the main engines and associated equipment.

The actual tests of propulsion machinery are made by the ship's engineering personnel, under the direction of the engineer officer. The ship is secured to the pier during this trial. The propulsion machinery and equipment must be tested sufficiently to ensure that it has been properly repaired and is in satisfactory operating condition. Any defect, deficiency, or maladjustment must be corrected either by ship's force or by shipyard personnel. The dock trial is repeated as often as necessary until conditions are satisfactory.

MATERIALS

One of the major problem areas for the engineering department is a lack of knowledge of the supply system. The Navy supply system is responsible for procuring, storing, delivering, and accounting for all materials used in the Navy. This responsibility also applies at the shipboard level; but, while one department may have the responsibility for a specific function aboard ship, it usually requires the cooperation and assistance of other departments to discharge that responsibility.

To satisfy the requirements of material reporting and accounting, the Navy divides material into five categories: (1) equipment, (2) equipage, (3) repair parts, (4) consumable supplies, and (5) services.

Equipment is considered to be any functional electronic, ordnance, hull, mechanical, or electrical unit that is operated singly or as a component of a system or subsystem and that is identified by a Component Identification Description/Allowance Parts List (CID/APL). Examples of equipment are turbines, pumps, and electric motors.

Equipage is an item of a durable nature that is not altered or consumed in use and is essential to the ship's mission. The allowance of equipage can be and usually is determined on an individual ship basis and is contained in allowance parts lists (APL), allowance equipage lists (AEL), or other authorization issued by commands, bureaus, or offices. Equipage items differ from equipment in that they are usually portable and pilferable. Some examples of equipage are typewriters, portable power tools (electric drills and pneumatic hammers), life preservers, special clothing, and test sets.

A repair part is any item that appears in an APL, a manufacturer's instruction book, technical manual, or a similar parts list. Consumable materials, such as gaskets, that have an equipment application are also considered repair parts.

Consumable supplies are administrative and housekeeping items, general-purpose hardware, common tools, or any other item not specifically defined as equipage or repair parts.

Services are nonmaterial requirements such as equipment rental, commercial telephone, pilotage, and tug hire.

CASUALTY REPORTS

A CASREP is a message report submitted by the commanding officer (or officer in charge) of a naval ship, craft, shore activity, or overseas base involved in a significant casualty. The casualty must affect equipment essential for the performance of designated missions and tasks. The CASREP system is the primary means of reporting the current material readiness status of a reporting unit with a diminished combat readiness posture. Account system or requirement redundancy involving inoperative or malfunctioning equipment is taken into account.

The CASREP system is a key element in the analysis and improvement of fleet material condition. It includes not only the initial casualty report, but also the follow-up situation reports (UPDATEs) and amplifying messages and correction reports.

The CASREP system also includes reports of disasters and/or mishaps involving loss of capability, material damage, and personnel injury resulting from collisions, strandings, fires-at-sea, missing or sunk submarines, and damage resulting from natural causes such as hurricanes, typhoons, earthquakes, and tidal waves.

Periodic review and analysis of CASREP data provide a strong indication of operational, maintenance, and supply problems. All elements of NAVSEA usually take prompt and agressive action in response to fleet CASREPs if NAVSEA material is involved. This is to maintain material readiness of the operating forces at the highest possible level.

Your ship's directives plus TYCOM instructions give the necessary information needed to form a CASREP.

ALLOWANCE EQUIPAGE LIST

The allowance equipage list (AEL) is similar in appearance to the APL; but whereas the APL is designed to provide maintenance and repair support for the ship's equipment, the AEL provides allowances of equipage and supplies necessary to support the ship's mission. The APL provides technical information for the person maintaining a piece of equipment and tells the supply officer what repair parts are necessary in the storeroom to support it. The AEL tells the commanding officer, supply officer, and other heads of departments what equipage and supplies are required to enable the ship to operate efficiently and effectively.

Through the use of AELs, an equipage allowance can be tailored to fit the needs of a specific ship. When the ship's equipage allowance is established, the commanding officer becomes responsible for carrying the full allowance on board. The consumable supplies listed on the AELs are not mandatory allowances, but they do provide a guide for the supply officer and department heads to use in determining what should be ordered.

NAVSUP Form 1250

Requests for material are submitted on the Single Line Item Consumption/Management Document (Manual), NAVSUP Form 1250. This form was developed to meet two needs: (1) improving stock control procedures and (2) reporting consumption under the Maintenance Data System (MDS) of the Navy Maintenance and Material Management (3-M) Systems.

The department representative may present a partially prepared NAVSUP 1250, or the form may be completely prepared by supply personnel, depending upon supply department instructions and existing conditions aboard ship. In either case, certain information must be furnished by the department representative.

When the material is received, the department representative receipts for it on the NAVSUP 1250 and is given the yellow copy of the form.

When material is drawn from stock, the "Approved by" signature (block 30) is not required since the engineer officer has already authorized certain persons to draw material either by memo or credit card.

NAVSUP Form 1348-6

Unfortunately, not all repair parts required to maintain engineering equipment has an NSN nor are they carried in the supply system. This is largely due to two factors: (1) the age of some equipment and (2) the fact that some equipment

is supplied by many different manufacturers. It is just not practical to invest large sums of money in maintaining inventory of repair parts that have limited application and usage.

When a repair part is required for which no NSN can be determined, the part must be ordered with the manufacturer's part or reference number as its identification. To ensure that the supply activity has sufficient information to process the requisition, the identification data portion of the NAVSUP 1348-6 should be completed and submitted with the NAVSUP 1250. Supply then forwards the completed NAVSUP 1348-6 to the supply activity using the information contained in the 1348-6; the activity can cross-reference the part to an NSN, if one is assigned, or purchase the part from the manufacturer.

NAVSUP Form 1250-2

The Non-NSN Requisition (NAVSUP Form 1250-2) consolidates on one form the information previously submitted on two (NAVSUP Form 1250-1 and DD Form 1348-6) for non-NSN requirements. Distribution and preparation of this new seven-part form is identical to the NAVSUP Form 1250-1. Additional information on this form can be found in *Afloat Supply Procedures* (NAVSUP P-485).

FINANCIAL CONTROL OF SHIP'S OPERATING TARGET (OPTAR)

The purpose of this section is to explain briefly how the Navy is funded and the method used to finance the day-to-day operation of ships.

With few exceptions (shipbuilding, alteration, research, and development), the Navy is funded by annual appropriations which are included in the Defense Appropriations Act passed each year by Congress. The money is made available to the Navy in the form of appropriations which are assigned to the various systems commands and bureaus who are responsible for administering them. Appropriation 17-1804, which is for operations and maintenance of the ships, is administered by NAVSEA and distributed through the fleet commanders. The fleet commanders grant operating budgets to each type commander under their command to enable them to carry out their missions.

The type commanders grant obligational authority, or OPTAR, to the ships within their commands for procurement of supplies and equipage. While the fleet accounting office performs the accounting required for the operating budget, the supply officer of each ship must maintain records in sufficient detail to enable the commanding officer to determine the status and ensure the proper and efficient use of the OPTAR. The budgeting for the initial grant is performed by the type command (TYCOM), with this method of requesting augmentation and the justification required established by the TYCOM.

Two terms, *Navy Stock Fund* (NSF) and *Navy Stock Account* (NSA), are frequently used in connection with supply operations and a brief explanation of their purpose will serve to give a better understanding of supply accounting.

The NSF is a revolving fund established to finance procurement of material. After procurement, the material is held in an inventory account, NSA. Thus, the NSF inventory is that material carried at ashore supply activities and on some supply ships.

When a ship submits a requisition and the material is issued, the NSA is reduced. The amount of the issue is charged to the ship's OPTAR and credited to the NSF, which may then use the money to procure replacement inventory.

The Appropriations Purchases Account (APA) is another inventory account that is used extensively. The APA material has been purchased with appropriated funds and is held in store awaiting issue. It is usually used for items of major equipment, such as NAVSEA controlled test equipment. When this material is requisitioned by the ship, the OPTAR is not reduced since the material has already been charged to "end use." A statistical charge is made for the purpose of accumulating total operating cost within the Navy.

Under current accounting procedures, operating costs are accumulated according to the purpose or type of expenditure and are identified by fund codes. The type commander designates the fund codes that may be used by each ship and specifies under what circumstances they may be used. Generally, the fund codes used aboard ship identify expenditures for equipage, repair parts, consumables, and services. The OPTAR grant may specify limits for each of these categories.

Fund codes must be carefully assigned on the NAVSUP 1250 (discussed earlier) to prevent incorrect charges to these categories.

As stated earlier, the commanding officer is responsible for the proper and efficient use

departments in the form of a budget. The use of the budget is optional, but it has proved its effectiveness. When departmental budgeting is used, the supply officer maintains budget records in conjunction with the OPTAR records. A 10-day report of the OPTAR and budget status is made to the commanding officer with a copy to each department. For example, the pink copy of each NAVSUP 1250, which has been processed by supply and charged to the engineering department budget during the preceding week, is included with the departmental copy of the budget report. This enables the engineer officer to reconcile the department record with supply records.

Departmental budget or expense records are maintained at the option of the engineer officer.

One way in which the engineering department can greatly enhance its readiness is to devote particular attention to its departmental supply petty officer records maintained by the various work centers. Complete and accurate records provide the engineer officer much better control over the allotted funds. Navy directives presently call for periodic validation of outstanding requisitions in order to justify the continued demand. Poor records result either in the cancellation of required parts or in tying up the ship's funds in parts that are no longer needed, when the funds could be used to meet present demands. So it behooves the engineer officer to ensure that the records accurately reflect current requirements. Relying on the memories of senior enlisted personnel, or even the engineer officer's memory, is a poor substitute for accurate records. Personnel are constantly being transferred, but records stay behind. Proper records are the solid foundation on which to build the department's corporate memory system as well as to enhance the department's repair efforts.

A little work at the beginning can save a lot of work, confusion, and frustration later, especially when it prevents the embarrassment of either wasting money on parts no longer needed or of waiting a long time for needed parts only to find out later that they were not properly ordered, or were ordered in insufficient quantity. At that point it is more than a squabble between the supply and engineering departments to determine whose fault it was. Rather, it is a matter affecting the operational readiness of the ship. Therefore, the proper maintenance of departmental supply petty officer records plus timely coordination with

COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL)

The COSAL is a technical and supply management document designed to enable ships to achieve maximum operating capability for extended periods of time, independent of external logistic support.

The COSAL is technical in that it provides nomenclature, operating characteristics, specifications, parts lists, and other technical data pertaining to all installed equipment and machinery, and nomenclature and characteristics of the equipage and tools required to operate and maintain the ship and its equipment.

The COSAL is a supply management document in that it tells the supply officer how much of what material to stock in the storerooms and the allowance of equipage items that must be carried aboard ship.

The allowances of material to be carried in the storerooms and material required in the operating spaces are prepared by computers from the hundreds of APL/AELs that apply to an individual ship. The preparation of these allowance lists takes into account all of the installed equipment on board, the failure rate of parts, and the relative importance of these parts to the operation of the equipment.

Of course, the COSAL will not provide parts for every equipment breakdown. To do this, a complete set of spare equipment and machinery would have to be carried on board, which is impossible.

The Ships' Parts Control Center (SPCC) is responsible for publishing the COSAL, which covers hull, mechanical, electrical, ordnance, electronics, nuclear weapons, and nuclear power plant equipment. The COSAL includes an introduction section that gives detailed descriptions of its various parts and their contents, and information that will be helpful when using them.

SUMMARY

This chapter has covered the basic responsibilities and administrative procedures associated with ship repair and alteration. Also covered briefly were the types of funding used to support a ship's supply and overhaul requirements, and the various boards and programs used by the Navy to oversee the maintenance of its ships.

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